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ABSTRACT

The federal government's budgeting process for allocating resources to research and development (R&D) is described. The report includes: The FY 1980 Budget and R&D: R&D Policies in the FY 1980 Budget: The Budget Statistics for R&D: Agency R&D Trends: R&D in Industry: and International Aspects of R&D. (MK)

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RESEARCH & DEVELOPMENT
AAAS REPORT IV

Federal Budget: FY 1980
Industry
International

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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A Report
prepared for the Executive Officer
and the AAAS Committee on
Science, Engineering, and Public Policy

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The AAAS Board of Directors, in accordance with Association policy, has approved publication of this study as a contribution to the understanding of an important process. The interpretations and conclusions are those of the authors and do not purport to represent the views of the Board or the Council of the Association.

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General Notes

1. Due to rounding in the tables, detail may not add to the totals, and percent changes may not correspond exactly to the differences shown.
2. Conversions to constant fiscal year 1972 dollars have been made by the authors using OMB factors for Table 20 in the *FY 1980 Budget*.
3. Conversions to constant calendar year 1972 dollars have been made by the authors using the annual calendar year GNP implicit price deflators for federal purchases of goods and services of the Department of Commerce, Bureau of Economic Analysis for 1978 and prior years; projections for 1979 and 1980 are based on the total GNP deflators contained in the President's *FY 1980 Budget*.

Foreword

What started 4 years ago as an experiment in policy analysis has by now matured into a substantial AAAS project focused on the federal budget process as it affects scientific research and development. Coupled with the annual AAAS Colloquium on R&D Policy in Washington, the report is a springboard for convening officials from the White House and Congress, industrial executives, academic scholars, and science policy watchers into lively discussion and argument about the American structure of research, development, and innovation. Another value from the Association's point of view is that the project is involving a growing number of AAAS's affiliated societies in the examination of the budget process and its outcomes. Finally, and significantly, the work has preserved its objectivity and steered clear of self-serving advocacy. The officers of AAAS are grateful to the report's authors, Willis H. Shapley and Don I. Phillips, to the Committee on Science, Engineering, and Public Policy, and to the Sloan Foundation which helped with seed money.

As this fourth report in the series shows, the federal budget is considerably more than a numbing array of numbers. It is a system for resolving issues and determining priorities. The presidential budget for 1980, in particular, furnishes a window on the implicit and explicit choices that will shape the scale and quality of U.S. science and technology in the coming years. What can be traced through the four AAAS reports is the incremental progress made by governmental machinery toward a stable "science and technology policy." As that policy becomes visible in its principal outlines, it invites reflection, analysis, and criticism. The AAAS report and the ensuing colloquium serve as timely feedback systems and are increasingly accepted as just that. Our hope, however, is that the arena of concern and debate will not be limited to what the AAAS tries to do, and that the perspectives and issues that swim to the surface will be taken up in other forums, especially in the scientific and engineering communities, the centers of public policy studies, the science press, and the Congress.

WILLIAM D. CAREY
Executive Officer
American Association for the Advancement of Science

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We would like first to express our thanks to the AAAS Committee on Science, Engineering, and Public Policy for its continued interest and sponsorship of the AAAS reports on R&D budgets and policies, especially to Professor Melvin Kranzberg, Chairman of the Committee, and Professor Ben S. P. Shen, Chairman of the Subcommittee on the R&D Budget project. Neither they nor the members of their Committees are responsible for the content of the report—publishing deadlines make review impractical—but their advice has helped shape the report and has been valuable to the authors.

We are also grateful to the large number of persons in federal agencies, industry, and professional societies who made information available to us and helped us interpret it. Special thanks are due for the cooperation we received from the Office of Management and Budget, the Office of Science and Technology Policy, and the National Science Foundation. We should also give special thanks to the representatives of the eleven professional societies who cooperated with the AAAS in the *Intersociety Preliminary Analyses of R&D in the FY 1980 Budget*, published in February 1979; we have drawn on their work at several points in this report.

Mr. William D. Carey, Executive Officer of the AAAS, and Dr. J. Thomas Ratchford, Associate Executive Officer and Head of the Office of Public Sector Programs, have provided valuable advice and assistance. Gail Breslow was of great assistance in running down information and produced and proofed the manuscript and tables. Kathryn Wolff and Anne Holdsworth in the AAAS Publications Office have done their usual first-rate job of getting the manuscript in shape for and through the press.

The preparation and publication of the report were supported in part by the Alfred P. Sloan Foundation, whose interest and help are once again gratefully acknowledged. Responsibility for the opinions and errors in the report is ours.

WILLIS H. SHAPLEY
DON I. PHILLIPS

Washington, D.C.
April 1979

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Introduction

This is the fourth annual report on research and development budgets and policies, prepared for the AAAS in its Office of Public Sector Programs. Like its predecessors, which we shall refer to as *AAAS–I*, *AAAS–II*, and *AAAS–III*,[1] it is addressed to the scientific and technical community and to those in government, industry, universities, and the public at large who are concerned with R&D and the public policies related thereto.

The central theme in these reports is the analysis of the funding for R&D included in the President's budget each year and of the policies on which the budget recommendations are based. With this as a starting point, each report has sought to illuminate other significant areas of interest to the R&D community and of importance to public policy in science and technology. In 1976, *AAAS–I* provided a detailed exposition of the federal budget process for R&D and of policy issues of continuing concern. *AAAS–II* took a closer look at the congressional role in R&D budgeting and suggested a new conceptual basis for R&D budgeting. Last year, in *AAAS–III*, the scope of the reports was broadened beyond the purview of federal R&D to include figures on R&D in industry and a discussion of the impact of R&D on the economy.

AAAS–IV continues this pattern. The first five chapters take a close look at the R&D recommendations and policies associated with the President's FY 1980 budget. Chapter 6 updates the figures and policy outlook on R&D in industry. And, in a further broadening of scope, Chapter 7 examines the various international aspects of R&D and identifies some of the key issues.

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[1] Citations to these reports are found under Shapley et al. in the List of References. Citations to all publications referred to in this report are in one of four categories in the List of References: The "General" references include publications pertaining to R&D in the federal budget; the section headed "Agency Budgets" contains citations to congressional budget justifications of the individual agencies and special reports on agency R&D budgets and programs; and "R&D in Industry" and "International Aspects of R&D" include citations to the documents related to the final two chapters of the report.

One of the principal purposes of the reports is to provide the basis for an annual AAAS-sponsored colloquium on R&D policy in Washington, D.C., at which senior officials of the Executive Branch, members of Congress, and other government officials meet with leaders and concerned individuals from industry, universities, and the scientific, technical, and public policy communities. The frank interchanges on problems and issues of mutual concern at these colloquia have served to promote a heightened awareness of R&D problems on the part of responsible government officials and a more balanced understanding of the government's problems in R&D on the part of the scientific and technical community.[2]

It must be emphasized that the role of this report, and the role of the AAAS in sponsoring both the reports and the colloquia, is not one of special pleading—for R&D programs or budgets, or for any particular point of view on controversial issues. The aim is simply to foster wider and clearer understanding of the important issues of R&D and public policy.

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[2] Citations to the proceedings of these colloquia are found under Blanpied et al. and Phillips et al. in the "General" section of the List of References.

RESEARCH & DEVELOPMENT
AAAS REPORT IV

Chapter 1

The FY 1980 Budget and R&D

We will begin our examination of R&D in the FY 1980 budget with a quick look at the overall budget for FY 1980 in its economic and political context. How did R&D fit into the bigger picture from a policy standpoint? How did the decisions that shaped the budget affect decisions on R&D? How does R&D fit into the overall spending plans projected in the budget?

A. The Overall FY 1980 Budget

The shape of President Carter's third budget was forged in the shadows of worsening inflation and rising public resistance to taxes. Conventional economic wisdom calls for reduced federal spending to restrain inflation; prudent politics calls for staking out a position on the popular side of a new issue with deep roots. It was no surprise, therefore, that the central theme of the President's FY 1980 budget was a strong pitch for fiscal restraint to combat inflation. Advance tipoffs drew fire from liberals worried about cut-backs in social and public interest programs; their concerns were heightened into an incipient guns versus butter debate by the President's refusal to back away from his commitment to NATO for a 3 percent real increase in U.S. defense spending. At the same time, conservatives watched with mixed emotions as a liberal President appeared about to emulate a liberal California governor and try to preempt two prime conservative issues—spending and defense.

The budget that emerged in January was tight on spending, but not as tight as liberals had feared. The 3 percent increase for defense was there, but so were most of their favored programs, with some trimming to be sure, but not abandoned. The economic assumptions in the budget were criticized from all sides as being over-optimistic; even fiscal conservatives recognized that a deficit larger than the President's figure of $29 billion would probably be necessary. As inflation jumped again in

the first months of 1979 and the energy situation was further confounded by the upheaval in Iran, it was becoming clear that traditional positions and rhetoric on budgetary economics might have to be revised in a pragmatic search for actions that might mitigate a very serious economic outlook.

B. The Posture on R&D

Along with other client groups heavily dependent on federal support, the R&D community—in Washington, at least—was apprehensive as the FY 1980 budget was being put together behind closed doors. The tough budget talk from the Office of Management and Budget (OMB) and White House sources, though discountable at this time of year as a normal adjunct to budget and political bargaining, sounded more convincing than usual.

There were also signs, however, that the budget might not be a disaster for R&D. It was known that the President's science adviser and the director of OMB had once again directed a joint letter to agency heads reminding them to take into account the importance of basic research in ranking the relative priorities of their programs in the zero-base budget process. Even better news was the specific exception in favor of R&D made by the President in his major speech in October 1978 calling for strict economy in federal spending as one of the main thrusts of his anti-inflation program; his discussion of the need to improve economic productivity included the statement that "federal support for research and development will continue to increase, especially for basic research." This, however, left unanswered the question of which programs would be increased, and skeptics could still wonder if the increases would turn out to be apparent (less than inflation) rather than "real."

The answer came during the week of January 22, 1979. The Budget message and the State of the Union message made it clear that the administration was indeed giving basic research both a special status as a matter of policy and a substantial real increase in the actual budget numbers. The policy position on other aspects of R&D was also positive but stressed the need for selectivity. As our analyses will show in detail later, budget policies and dollars in R&D areas other than basic research for the most part conformed to the generally restrictive pattern of the rest of the budget. There were increases, but only a few exceeding the anticipated rate of inflation.

C. R&D in the Total Budget Context

Leaving the details of R&D policies and budgets to the next chapter, let us look now at how the planned spending for R&D relates to the total budget.

Table 1a shows the general picture in current dollars. Total outlays for R&D are estimated at $31.2 billion in FY 1980, 5.86 percent of the total outlay budget of $531.6 billion and 1.24 percent of the total estimated gross national product (GNP) of $2.5 trillion. The R&D percentages of total budget outlays and total GNP are about level over the 3 years FY 1978 through FY 1980, but are substantially below the corresponding figures for FY 1972, chiefly because of the enormous increases since that time in federal outlays for payments to individuals and grants to states and localities but also because of the growth in the GNP. The

Table 1a. Budget Summary and R&D Outlays in Relation to Other Outlays and GNP, FY 1980 Budget, Current Dollars (in billions).

	FY 1967 Actual	FY 1972 Actual	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget
Outlays					
Research & development					
Basic research	$ 1.6	$ 1.9	$ 3.4	$ 3.9	$ 4.3
Applied research	2.9	3.7	5.5	6.1	6.6
Development	11.6	10.5	15.6	17.6	18.8
TOTAL conduct of R&D	$ 16.1	$ 16.2	$ 24.5	$ 27.6	$ 29.7
Facilities	0.8	0.6	1.1	1.3	1.5
TOTAL R&D outlays	$ 16.9	$ 16.7	$ 25.6	$ 28.9	$ 31.2
National defense R&D	(8.3)	(9.0)	(12.2)	(13.6)	(15.1)
Other R&D	(8.6)	(7.7)	(13.4)	(15.3)	(16.1)
National defense[1]	59.9	67.6	93.0	100.9	110.8
Payments & grants[2]	50.2	106.1	248.3	268.4	292.5
Interest	10.3	15.5	35.4	43.0	46.1
All other	21.0	26.1	48.4	52.1	51.1
TOTAL budget outlays	$158.3	$ 232.0	$ 450.8	$ 493.4	$ 531.6
Receipts	$149.6	$ 208.6	$ 402.0	$ 456.0	$ 502.6
Deficit	$ 8.7	$ 23.4	$ 48.8	$ 37.4	$ 29.0
TOTAL GNP	$774.4	$1110.5	$2043.4	$2289.4	$2505.7
Total R&D outlays as percent of					
Total outlays	10.65%	7.22%	5.69%	5.86%	5.86%
GNP	2.17%	1.51%	1.25%	1.26%	1.24%
Basic research outlays as percent of					
Total outlays	1.02%	0.84%	0.76%	0.78%	0.82%
GNP	0.21%	0.17%	0.17%	0.17%	0.17%

Source: Authors' estimates based on OMB data for Tables 19 and 20 in the *FY 1980 Budget* and for "Special Analysis L," and *Federal Funds*, Volumes XXV and XXVII, NSF.

[1]Excluding R&D.

[2]Payments to individuals and grants to states and localities, excluding R&D.

special emphasis on basic research in the FY 1979 and FY 1980 budgets is apparent in the increase from 0.76 percent in FY 1978 to 0.82 percent in FY 1980 in basic research outlays in the total budget.

Perhaps the most important point brought out by Table 1a is the magnitude of R&D outlays in relation to other general expenses of the federal government, that is, expenses exclusive of payments to individuals, grants to states and localities, and interest. National defense R&D represents over 10 percent of total outlays for national defense. Even more striking is the fact that nondefense R&D outlays are almost 24 percent of all outlays for nondefense general expenses other than payments, grants, and interest. While R&D is scattered throughout the budget in many pieces, large and small, R&D in total—as a type of activity—is clearly a major claimant on the financial resources of the federal government.

Trends in the relative position of R&D outlays in the total composition of the budget are more clearly seen in Table 1b, where the outlay data in Table 1a have been converted to constant FY 1972 dollars. Here the figures show that total "real" dollars for R&D are increasing slowly and in FY 1979 and FY 1980 are estimated to go slightly above the base year of FY 1972, chiefly by virtue of a substantial increase in basic research. From FY 1972 to FY 1980, national defense R&D is down about 7 percent; all other R&D is up almost 17 percent. The overall net in-

Table 1b. R&D Outlays in Relation to Other Outlays, FY 1980 Budget, Constant FY 1972 Dollars (in billions).

	FY 1967 Actual	FY 1972 Actual	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget
Outlays					
Research & development					
Basic research	$ 2.2	$ 1.9	$ 2.2	$ 2.3	$ 2.4
Applied research	3.9	3.7	3.5	3.6	3.7
Development	15.6	10.5	10.0	10.5	10.5
TOTAL conduct of R&D	$ 21.7	$ 16.2	$ 15.7	$ 16.4	$ 16.6
Facilities	1.1	0.6	0.7	0.8	0.8
TOTAL R&D outlays	$ 22.8	$ 16.7	$ 16.4	$ 17.2	$ 17.4
National defense R&D	(11.2)	(9.0)	(7.8)	(8.1)	(8.4)
Other R&D	(11.6)	(7.7)	(8.6)	(9.1)	(9.0)
National defense	80.8	67.6	59.5	60.1	62.0
Payments and grants	64.0	106.1	158.6	158.1	161.1
Interest	16.1	15.5	17.8	17.5	17.2
All other	28.4	26.1	30.9	31.2	28.5
TOTAL budget outlays	$212.1	$232.0	$283.2	$284.1	$286.2

Source: Conversion of data in Table 1a to constant FY 1972 dollars based on OMB factors for Table 20 in the *FY 1980 Budget*.

crease of 4 percent in R&D outlays from FY 1972 to FY 1980 contrasts, on one hand, with a decrease of about 8 percent in national defense and, on the other hand, with the 52 percent increase in payments and grants that is the real cause, apart from inflation, of the growth in the federal budget during this period. Comparing FY 1980 with FY 1979, we see this overall pattern: more growth in payments and grants, the promised 3 percent real increase for national defense, the budget squeeze on all other general expenses, and R&D holding its own with a slight gain.

D. The Central Problem of Inflation

The trends indicated in Table 1b reflect accurately the intentions and hopes of the administration, but their validity as a forecast, or even as a basis for substantive analysis, is open to serious question. Here, and in the analyses of budgetary trends throughout this report, we face the overriding uncertainty of inflation. What rates of inflation will actually occur in FY 1979, FY 1980, and beyond?

For consistency with the FY 1980 budget, our conversions of budgetary statistics to constant FY 1972 dollars, for Table 1b and throughout the report, are based on the pertinent inflation rates assumed and projected in the President's budget and supporting documents. For FY 1979 this is an annual average rate of 7.06 percent; for FY 1980 it is 6.56 percent. With actual inflation approaching double-digit rates in the first months of calendar year 1979 and no signs of a turn-down, the rates assumed in the budget—optimistic in any case—seem clearly low by a couple of points in FY 1979 and perhaps even more in FY 1980.

Higher inflation rates will necessarily erode the amount of R&D work that can be conducted with the dollar amounts included in the FY 1980 budget. Except in the unlikely event that additional dollars are provided in supplemental budgets, each program will feel an additional squeeze to the degree that the actual costs encountered exceed the funds available. While the actual impacts will vary from case to case, it is possible to assess the effect in total. Thus, for example, if actual inflation is 9 percent in both FY 1979 and FY 1980, the result would be an average squeeze of about 4 percent on the R&D dollars budgeted for FY 1980—effectively a cut of about $1.25 billion in the $31 billion total. Rising inflation, and the uncertainties of how much it will rise and what the impacts will be, are crucial problems facing federal R&D (and everyone else!) for FY 1980.

E. Investment and the Future

Even though clouded by inflation, the outlay estimates in the FY 1980 budget do provide some further insights as to the place of R&D in overall federal budget planning. We will briefly note two.

Table 2. R&D and Other Investment-type Outlays, Current Dollars (in billions).

	FY 1967 Actual	FY 1972 Actual	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget
Investment-type outlays					
Research and development	$ 16.9	$ 16.7	$ 25.6	$ 28.9	$ 31.2
National defense[1]	*	*	22.9	25.4	29.0
Civil construction[1]	*	*	23.3	23.8	22.9
Education and training	*	*	18.4	21.1	21.0
Other investment-type	*	*	14.5	13.8	11.4
TOTAL investment-type outlays	$ 68.2	$ 66.0	$104.7	$113.0	$115.5
Current program outlays	90.1	166.0	346.1	380.4	416.1
TOTAL outlays	$158.3	$232.0	$450.8	$493.4	$531.6
R&D as percent of total investment-type outlays	24.8%	25.3%	24.5%	25.6%	27.0%

Source: "Special Analyses D and L," *FY 1980 Budget*, and corresponding data in *FY 1969* and *FY 1974 Budgets*.
*Not available.
[1] Excluding R&D.

First, R&D as an investment. R&D is increasingly being recognized as an investment expense rather than current operating expense, and is so characterized in both the State of the Union and Budget messages and in the President's subsequent special message on science and technology. Table 2, based on "Special Analysis D" of the *FY 1980 Budget*, shows how past and estimated R&D outlays relate to other federal investment-type outlays. The increasing percentages of R&D in relation to total investment-type outlays from FY 1978 to FY 1980 show that the net effect of federal budgetary policies in FY 1979 and FY 1980 has been to enhance federal investment in R&D. By contrast, investment in civil construction and the "other" category (largely loans and other financial investments) is down, both relatively and in current dollars, and the education and training category is just about holding its own. Only investment in military hardware is increasing more than investment in R&D. The data for FY 1967 and FY 1972 indicate some stability over the years in a pattern wherein about one out of every four dollars "invested" by the federal government has gone to R&D.

Second, we should look at what the FY 1980 budget seems to hold for the years after FY 1980. As we shall discuss in a later section, the administration has made a special point that the FY 1980 budget reflects a newly instituted 3-year budget planning system to gain better control of the longer-range effects and directions of government policies. While R&D as a whole is not one of the categories for which explicit budget planning is included in the FY 1980 budget, the additional data that are

presented on a 3-year basis permit us to derive some estimates of what current planning holds for R&D.

Table 3 shows estimated total outlays for R&D in relation to the same major categories of expenditure we used in Tables 1a and 1b. Within the policies and economic assumptions of the FY 1980 budget (including projection into the future of the optimistic assumptions of lower inflation rates discussed above), the budget outlays estimated for FY 1981 and FY 1982 appear to call for a 10 percent increase in total R&D outlays in FY 1981 in current dollars, followed by about a 5 percent increase in FY 1982. In constant dollars, at the optimistic inflation rates assumed, the real increase in FY 1981 would amount to less than 5 percent and FY 1982 would bring a slight decline. The estimates indicate that the FY 1981 increase in R&D is primarily on the national defense side. Our analysis later will suggest that the apparent tilt toward defense

Table 3. R&D Outlays for FY 1981 and FY 1982 in Relation to Other Outlay Estimates, FY 1980 Budget (in billions).

	FY 1980 Budget	FY 1981 Est.	FY 1982 Est.
Current dollars			
Research and development			
National defense	$ 15.1	$ 17.1	$ 18.1
All other	16.1	17.2	17.7
TOTAL R&D	$ 31.2	$ 34.3	$ 35.8
National defense[1]	110.8	119.9	130.1
Payments and grants[1]	292.4	315.4	335.8
Interest	46.1	46.7	45.0
All other	51.1	61.7	68.2
TOTAL outlays	$531.6	$578.0	$614.9
R&D as percent of total outlays	5.86%	5.94%	5.83%
Constant FY 1972 dollars			
Research and development			
National defense	$ 8.4	$ 9.1	$ 9.1
All other	9.0	9.1	9.0
TOTAL R&D	$ 17.4	$ 18.2	$ 18.1
National defense[1]	62.0	63.4	65.6
Payments and grants[1]	161.1	163.8	166.4
Interest	17.2	16.2	15.5
All other	28.5	32.6	34.3
TOTAL outlays	$286.2	$294.2	$299.9

Source: Authors' estimates based on estimates in Part 5 and OMB data for Table 20 in the *FY 1980 Budget*.

[1] Excluding R&D.

R&D may be only a statistical reflection of the availability of detailed planning on the defense side, as opposed to the use of simple extensions of current budget levels in most civil R&D programs.

Chapter 2

R&D Policies in the FY 1980 Budget

In this chapter we will examine the policies applied to R&D in the FY 1980 budget. Starting with the policy foundations laid down in the FY 1979 budget, we will review briefly the congressional impact on FY 1979 and development of the FY 1980 budget. Then we will examine the R&D policies presented in the President's Budget and State of the Union messages and in his subsequent special message on science and technology.

A. Foundations for FY 1980

The R&D policies in the FY 1980 budget built on and reinforced those of the FY 1979 budget, the first to be fully developed by President Carter's administration. The R&D policies embodied in the FY 1979 budget, discussed in detail in *AAAS III*, were in brief as follows:

(i) A generally positive attitude toward R&D and science and technology.

(ii) A strong special emphasis on basic research and the need for a real increase in federal support, based on a rationale stressing the coupling of basic research and economic benefits.

(iii) Clear acceptance of a federal responsibility for the support of basic research because of inevitable underinvestment by industry; also an expressed hope that industry would increase its own support of basic research.

(iv) Rejection of the notion that federal support of research implies a federal policy of support of universities as institutions, but expectation that increased federal support of basic research would alleviate university problems.

(v) Continued strong and increasing support for national

defense R&D, including basic research in the Department of Defense.

(vi) Selective support for development and demonstration projects in energy and other nondefense areas, in order to avoid federal preemption of the private sector, investment in unneeded technologies, or duplication of demonstrations.

These policies as such were not controversial in Congress, but the specific FY 1979 budget recommendations to implement them met a mixed fate, as discussed in the AAAS report *Congressional Action on Research and Development in the FY 1979 Budget*. Basic research was indeed increased in total, even above the budget recommendations. The increase came, however, mostly in a big boost over the budget for health research, whereas the increases budgeted for the National Science Foundation (NSF) and most other agencies were trimmed back. Specific basic research initiatives of the Departments of Agriculture and Defense were rejected. In total, Congress made cuts in R&D amounting to about $425 million, mostly in Defense, and increased other R&D by about $741 million—a net increase of about $316 million over the budget. Congress had its own ideas on selectivity in development and demonstration projects and made some significant rearrangements in Defense and Energy programs. Nevertheless, even though Congress left its mark, most of the R&D which was recommended in the FY 1979 budget was approved as submitted.

While mid-course corrections for FY 1979 were being made by Congress, the Executive Branch was busily engaged in further development and refinement of administration policies related to R&D and in putting together the FY 1980 budget. The large-scale interagency study of innovation, heralded in the FY 1979 budget, finally got underway under the leadership of the Department of Commerce. New policy papers on space activities were finally approved, generally endorsing currently planned federal activities in space-related R&D. Special task forces made recommendations on basic research in the Department of Defense and the Department of Energy. Work and negotiations with the university community continued on revisions to the celebrated (or infamous!) Circular A–21 on indirect costs and accountability for federal research at universities. Policy and procedural problems in areas like carcinogen identification received special attention. In sum, the "system"—Office of Science and Technology Policy, OMB, and the agencies—was actively coping with the policy problems of federal R&D.

B. The Budget Decision Process

The preparation of the FY 1980 budget generally followed the normal tedious pattern. Agencies started internal work preparing the FY 1980 budget in the spring, using the FY 1979 budget decisions as a start-

ing point. Target ceilings were given to the major agencies during the summer. Detailed budget estimates were sent to OMB in September, with "decision packages" ranked in priority order in accordance with the Carter administration zero-base budget (ZBB) procedures. Agency leaders and budget officers wrestled with OMB examiners on points at issue. With some consultation with the Office of Science and Technology Policy (OSTP) and other Executive Office units, OMB firmed up recommendations and options for decisions by the director of OMB and the President. Agency heads had opportunities to negotiate and appeal. When final decisions were made, there was the usual crush to produce and print the more than 2000 pages of official documents comprising the President's budget and the tons of justifications and supporting materials the agencies must provide to Congress.

Within this pattern there were some variations and innovations from prior years. With the maturing of his administration, the President was able to reduce his personal participation and rely on his budget director to resolve a large portion of the issues. An innovation in the process was some attempts at "interagency zero-base budgeting" (IZBB), where decision packages in related programs of several agencies were integrated into a single list to permit their relative priorities to be considered in a broader context. The most important innovation, announced in the FY 1979 budget, was to be the introduction of a 3-year budget planning system. Agencies were required to submit estimates for FY 1981 and FY 1982 as well as for FY 1980. The budget decisions made or approved by the President included at least a total figure for each agency and functional category for the 2 extra years. The FY 1981 figures and the decisions that went into them are to be taken as the planning base for the preparation of the FY 1981 budget. The experiment may have fallen short of providing true 3-year program plans in most cases, but it seems to have been a step toward more explicit long-range thinking in the preparation of the annual budget.

For R&D, the decision process followed the overall pattern, but with the special feature of active participation by OSTP. As already mentioned, the directors of OSTP and OMB sent a joint letter to agency heads to assure proper treatment for basic research. OSTP monitored the budget process to see that policies on R&D-related matters were properly reflected in the budget decisions and participated actively in the negotiations in some cases. The President was kept informed on R&D aspects of the budget; there was a newspaper report that he gave personal instructions that the total for R&D should be allowed to increase to the same degree as the overall budget total. OMB held special interagency reviews of some R&D crosscut areas, for example of programs related to toxicity and the interagency program to develop agricultural crop forecasting from space. Budget decisions on basic research in the many agencies involved were centrally monitored by both OSTP and OMB, and the individual allowances were fine-tuned in the final days.

C. Budget and State of the Union Policies

With the major lines set in FY 1979, there was no clear need or expectation of major new general policy pronouncements on R&D in the FY 1980 budget. The R&D policies for the FY 1980 budget were indeed primarily a reaffirmation, with some changes in emphasis and some elaboration, of the policies stated a year before, not something new and different. This does not detract from their significance. In a year when previous policies might have been bent or abandoned to meet the exigencies of inflation, it was no small matter that the President decided to keep federal R&D on its previous course. In any case, consistency over a period of years is an essential ingredient of effective R&D policy.

The general R&D policies for the FY 1980 budget set forth in the Budget and State of the Union messages, as enunciated in the paragraphs quoted at the end of this section, can be summarized briefly as follows:

(i) The importance of basic research is again highlighted and vigorously reaffirmed. Further substantial real growth in basic research is included in the budget; the real growth policy in the FY 1979 budget was not a one-shot affair.

(ii) The rationale for federal support of basic research has been modulated to tone down last year's emphasis on economic benefits. First billing this year is given to the potential of basic research for breakthroughs to the solution of critical problems. The relevance of basic research to productivity and the relation of increased productivity to reducing inflation are mentioned, but not as the principal justification for increasing federal support of basic research.

(iii) The need for greater selectivity in federal funding for demonstration and pilot commercialization projects is again stressed. The government will rely on industry to do its full part in this area.

(iv) Rather than federal funding, industry R&D requires a better investment, economic, and regulatory environment. The innovation study under the Department of Commerce, announced last year, is addressing these problems.

(v) A new institute for scientific and technological cooperation is proposed to foster collaborative efforts in science and technology with developing countries.

Some additional policies of general interest are implicit in the specific budget decisions we will be discussing later, for example:

(i) Continued increases are recommended for national defense R&D in both a supplemental estimate for FY

1979 and in the FY 1980 budget. The policy of annual real increases in Department of Defense research and exploratory development programs continues in effect.

(ii) Solar energy R&D gets strong encouragement in budget policy statements, in contrast to the restrictive attitude of a year ago.

(iii) Space R&D gets indications of continuing long-term support in accordance with the administration policy reviews completed in 1978.

(iv) In health research, a policy (or perhaps a tactical) decision was made to accept the substantially above-budget levels voted by Congress for FY 1979 and to propose holding to these levels in the FY 1980 budget.

(v) Special policy attention was given to interagency programs in several fields, including microelectronics, crop assessment from space, and toxicity, as well as to climate and earthquake research, which had also received special attention in previous years.

The text of the passage in the President's Budget message that pertains to R&D is as follows:

> Finally, I believe that the Federal Government must lead the way in investing in the Nation's future. This budget, therefore, continues my policy of providing real growth in Federal support of basic research. This support amounts to a relatively small part of the total budget—$4.6 billion in 1980—but it is vital to the future of our Nation. The knowledge created through basic research holds the potential for breakthroughs to the solution of problems we face or may face in such critical areas as agriculture, health, environment, energy, defense, and the overall productivity of our economy. Higher productivity gains in the future, moreover, will make an important contribution to reducing inflation.

The following is the relevant text from the State of the Union message:

> When I came into office, I found Federal efforts to promote basic research and development lagging. I was determined to change this situation and develop a sounder scientific and technological foundation for the future. Basic scientific research and development is an investment in the Nation's future, essential for all fields, from health, agriculture, and environment to energy, space, and defense. We are enhancing the search for the causes of disease; we are undertaking research to anticipate and prevent significant environmental hazards; we are increasing research in astronomy; we will maintain our leadership in space science; and we are pushing back the frontiers in basic research for energy, defense, and other critical national needs. Despite the severe budgetary constraints this year, we will continue to increase Federal support for basic research with a request for a 13% increase in outlays for FY '80.
>
> Even though Federal funding for basic research is being increased, I

believe that the government's role in demonstration and commercialization pilot projects should be more selective, with greater reliance upon private sector financing. We are enhancing our high technology approach to defense to counter the growth of Soviet forces. We have a broad energy research program that emphasizes long-term applications of solar, coal, geothermal, biomass, and alternate nuclear technologies. But we will rely on industry to do its full part in the demonstration of new technologies in energy and in other fields.

Rather than government funding of their research and development, companies need more favorable investment climates, better economic growth, better trade prospects, and sound policies about patents, antitrust, procurement, and environmental regulation. Under the direction of the Department of Commerce, we are also engaged in a major Cabinet-level review of these aspects of technological innovation, with participation of numerous individuals from various industrial sectors.

Science and technology are playing an important part in our international relationships as well. Many countries, especially developing countries, look to America for our expertise and problem-solving abilities. I have proposed the establishment of a Foundation for International Technological Cooperation (FITC) to foster collaborative efforts with people and institutions in developing countries. These efforts will be directed to basic human needs in agriculture, nutrition, health, small-scale energy systems, and rural development.

D. The President's Special Message

In the last week of March 1979, right after the signing of the Israeli–Egyptian peace treaty, there suddenly appeared a full-blown presidential special message to Congress on science and technology. There was little advance notice, no advance buildup, and virtually no public reaction. But there it was—the first comprehensive presidential statement of federal policies on science and technology and R&D.

The stated purpose of the 7500-word message was to articulate "a science and technology policy for the future. . . . The thesis is that new technologies can aid in the solution of many of our Nation's problems. These technologies in turn depend upon a fund of knowledge derived from basic research. The federal government should therefore increase its support both for basic research and, where appropriate, for the application of new technologies."

The body of the message begins with a summary and reaffirmation of the policies on federal support of R&D embodied in the FY 1979 and FY 1980 budgets that call for federal support of (i) R&D to meet direct federal responsibilities; (ii) R&D to accelerate when necessary the rate of development of new technologies in the private sector, but not of R&D having near-term commercial payoff; and (iii) basic research—both as a quest for new knowledge and as a "forerunner" of new capabilities, products, and technologies. It goes on to recite how science and technology hold the key to many aspects of the solutions to our domestic

problems: stimulating innovation in industry; meeting energy, natural resources, and food needs; providing better health; improving the regulatory process; expanding beneficial uses of space; and understanding the forces of nature, natural disasters, and changes induced by man.

The report then discusses the international dimensions of science and technology: international initiatives in R&D, scientific exchanges to bridge divisions between countries, help to developing countries in using science and technology, and cooperation with other nations to manage technologies with global impact. Next it summarizes the significance of technology to national security, stressing the importance of (i) maintaining technological leadership in weapons, (ii) using technology in reducing costs of expensive defense systems, (iii) building a defense research base to provide for national security in the future, (iv) preventing export of technologies that would erode our security, and (v) utilizing advanced technology in the pursuit of arms limitation agreements. Finally, in a section called "Harnessing the National Capability," there are some general words on federal government relations with universities and state and local governments, coordination within the federal government, cooperative activities between industry and universities, public understanding and participation in science and technology activities, science education, and the importance of commitments to continuity of policies and support.

In this far-ranging document, there are no new policy announcements or program proposals. The actions called for are congressional support of the FY 1980 budget recommendations, especially the increases for basic research, and more generally, of the framework of policies on which the budget is based. The bottom line is a call to Congress to join the administration "in its commitment to nonpartisan investment in science and technology for our future."

It has to be said, however, that the message, while styling itself a "policy for the future," does not spell out the meaning beyond FY 1980 of the "commitment" Congress is asked to join. One can, if one chooses, read into the words quoted above a policy of continuing future increases in "support both for basic research and, where appropriate, for the application of new technologies." But the only clear commitments are to policy direction, approach, and attitude.

Why was the message sent to Congress? Why at this time? In the absence of a significant new policy announcement or any other obvious occasion for the special message, one may speculate that several considerations converged to bring it about. One of these may have been a perceived need to defend in advance the budget recommendations for increases in basic research against unpleasant rumblings already being heard in Congress. The plugs for support of the basic research budget echo the letter that the President sent to Congress last year after cuts had already been made. Another consideration may have been a desire to make a strong showing—by the time of hearings scheduled for early April—of the administration's interest and progress in science and tech-

nology policy. One of the motivations may have been to counteract some negative impressions on the Hill stemming from the President's gutting by reorganization the detailed policy and reporting apparatus mandated in the Science and Technology Policy Act of 1976, the late submission of the first annual Science and Technology Report and the decision to skip a year before submitting the next, and possibly other instances where OSTP and the administration may have seemed less than fully responsive to the interests of Congress. Yet another possibility is that it was recognized as an opportunity to lay some groundwork for future presidential image-building with an eye to the 1980 political campaigns. Finally, it is always possible—although always hard for Washington hands to believe—that it is what it appears to be: a summary statement of federal science and technology policy and a call to Congress to give it support.

As such, it is a unique document. It contains little that is new, nothing that is spectacular, and no calls for heroic initiatives. But in its quiet way, it is an impressive, comprehensive statement, both thoughtful and authoritative, of the rationale, objectives, concerns, and future directions of the federal government's many interests in science and technology and R&D. It deserves careful reading in full, and it undoubtedly will be widely reprinted and circulated in the scientific, technical, and public policy communities. Critics who have cried in the wilderness for coherent federal overall policy in science and technology and R&D will now have the task of relating their expectations of what science and technology policy really should be to what has now been produced. Perhaps discussions of policy in the abstract or procedural terms can now give way to more fruitful discussions of issues and alternatives.

Chapter 3

The Budget Statistics for R&D

Now let us look at the statistics on R&D in the FY 1980 budget to see what they can tell us about the R&D the President and his administration have recommended in the FY 1980 budget.

A. The R&D Totals

To begin with, we have to switch gears. Our first look at the overall figures for R&D (in Chapter 1) was in terms of *outlays;* from now on we will be talking in terms of *budget authority.* Outlays, the actual or estimated amounts to be paid out by the government each fiscal year, are significantly determined by the amounts appropriated and obligated in the preceding year (or years, in the case of long-term contracts). Therefore, while outlays provide a good measure of budgetary trends over a period of years, they are not always a good indicator of the impact of budget decisions in a particular year. For this purpose, statistics on *obligations* (the amounts committed or contracted each year) or *budget authority* (the amounts appropriated for obligation each year) are better measures. Budget authority is our preferred measure because it is the basis on which the President and Congress act on the budget and because it avoids the estimating inconsistencies that sometimes afflict obligations estimates.

Table 4 gives the overall picture. It compares the estimated totals for R&D in the FY 1980 budget on all three bases; it shows that the totals for outlays and obligations lag behind those for budget authority, as would be expected in an increasing trend. In current dollars, total budget authority for R&D in FY 1980 is estimated to be 3.8 percent over the amount now estimated for FY 1979—a 15.7 percent increase over FY 1978 and an 87.8 percent increase since FY 1972. Correcting for inflation gives a different story, of course. The constant dollar part of Table 4 shows that even under the administration's optimistic assumptions on

inflation, total budget authority for R&D would decline by about 2.6 percent in real terms from FY 1979 to FY 1980. If inflation is 9 percent in both FY 1979 and FY 1980, the purchasing power of the R&D dollars budgeted for FY 1980 would be down almost to the FY 1972 level; that is, the 87.8 percent increase in current dollars would be less than 1 percent in real terms.

B. Qualifications and Distortions

Before carrying the analysis any further, we should pause to consider the nature and limitations of the statistical universe we are dealing with and to note some factors besides inflation that affect comparisons and interpretations. The figures in Table 4, like most of those elsewhere in this report, are not derived directly from the federal budget and accounting system. Federal R&D activities are spread through many different government agencies and parts of agencies, often commingled with other technical or operational programs. The budget statistics on federal R&D each year come from agency estimates put together by OMB and summarized in a special analysis ("Special Analysis L" this year) published at the same time as the President's budget; later in the year the figures are refined and published in the annual NSF *Federal Funds* reports.

OMB has once again kindly made available to the AAAS a full set of

Table 4. Total Federal Funding for R&D (in billions).

	FY 1967[1] Actual	FY 1972[1] Actual	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget
Current dollars					
Budget authority					
Conduct of R&D	$16.5	$16.5	$26.5	$29.5	$30.6
R&D facilities	0.6	0.6	1.3	1.5	1.5
TOTAL R&D	$17.1	$17.1	$27.8	$31.0	$32.1
Obligations, total R&D	17.1	17.1	27.5	30.8	32.2
Outlays, total R&D	16.9	16.7	25.6	28.9	31.2
Constant FY 1972 dollars					
Budget Authority					
Conduct of R&D	$22.3	$16.5	$16.9	$17.6	$17.1
R&D facilities	0.8	0.6	0.8	0.9	0.8
TOTAL R&D	$23.2	$17.1	$17.7	$18.5	$18.0
Obligations, total R&D	23.2	17.1	17.6	18.4	18.0
Outlays, total R&D	22.8	16.7	16.4	17.2	17.4

Source: "OMB Data for Special Analysis L" and *Federal Funds*, Volume XXV, NSF. Conversion to constant FY 1972 dollars by authors based on OMB deflators.

[1] Authors' estimates based on above sources.

the data assembled for the FY 1980 special analysis of R&D. For convenience, our overall tables and analyses will be based on the OMB data without correction, but several qualifications concerning the accuracy and comparability of the data should be recognized.

First, there are problems in establishing the boundaries for R&D. The official (NSF) definitions leave much room for judgment as to what activities should be included or excluded. As a result, the total R&D universe cannot be defined precisely, and there are problems in the stability of the estimates from year to year as differing judgments are applied. While the estimates each year for each item are presumably made on a comparable basis, they may not be consistent with the corresponding estimates in previous or subsequent years. Thus, the R&D statistical universe may expand or contract from year to year.

Second, even statistically comparable estimates can be misleading. In each year's budget presentation, the estimates for the current fiscal year are updated to reflect reprogrammings and other administrative decisions to change the amounts expected to be applied. They also include any current year *supplemental* budget estimates the President is recommending in the budget. In the OMB analysis, the fact that supplementals and other adjustments are included in the current year totals needs to be taken into account in assessing the amounts of increase or decrease in the budget year. Finally, as in any set of complex statistics put together from many sources under severe time pressures, there are always possibilities for just plain mistakes.

Tables 5a and 5b attempt to show the magnitude of these various types of distortions in the FY 1980 budget statistics for R&D. We see in Table 5a the adjustments which last year's estimated total for R&D in the FY 1979 budget has undergone: a budget amendment; congressional cuts and increases; and a large figure representing the net total of reprogrammings, reclassifications, errors, and adjustments (other than supplementals), indicating a substantial net expansion of the R&D universe during the past year. Comparing this adjusted base for FY 1979 with the FY 1980 total, we can see the impact of the $831 million of FY 1979 supplementals on statistical comparisons. Without the FY 1979 supplementals, the apparent increase in FY 1980 is 6.7 percent instead of the 3.8 percent calculated with the supplementals included. But the 6.7 percent figure is also not an accurate measure of increased R&D funding because the FY 1980 budget estimates include amounts to continue the FY 1979 supplemental programs, and without these amounts the percentage increase of the FY 1980 estimates would undoubtedly have been different—presumably lower.

Table 5b illustrates the magnitude of some other adjustments and corrections that might be made to the OMB budget authority totals. The R&D or R&D-related activities listed probably should have been included. The OMB figures included FY 1979 supplementals, as we have seen, but for some reason did not reflect the FY 1979 rescissions (appropriation reductions) recommended by the President. Supplemental amounts

likely to be needed in FY 1980 for federal pay raises were excluded by OMB ground rules which give such amounts separate treatment. Finally, some needed corrections in the OMB data have been identified. The net effects of all these adjustments, shown in the bottom line, give us still another figure, 4.7 percent, for the increase in FY 1980 over FY 1979. The significant point of this analysis, however, is not so much the identification of uncertainties and errors but the fact that the net amounts of the distortions in the totals are so small—less than 1 percent.

There are two other elements of federal support for R&D that are outside the R&D universe as generally conceived. One is the independent research and development (IR&D) that defense and certain other contractors are permitted to charge as an overhead expense to federal contracts; this has been estimated to run as high as $500 million per year. The other consists of so-called tax expenditures for R&D, representing the revenues foregone by the government because of special write-off provisions for company R&D expenditures in the Internal Revenue Code. The FY 1980 budget estimates these write-offs at $1.8 billion in FY 1980.

Table 5a. Comparison of Total Estimates of R&D in the FY 1979 and FY 1980 Budgets (Budget Authority in millions).

	FY 1978	FY 1979	FY 1980
Total R&D in FY 1979 budget (OMB "Special Analysis P")	$27,377.5	$29,197.0	
Budget amendment		50.5	
TOTAL budgeted		$29,247.5	
Congressional actions (AAAS est.)			
Reductions		−425.1	
Increases		+740.6	
Total approved by Congress		$29,563.0	
Reprogrammings, reclassifications, and other adjustments (net)	+387.7	+562.6	
BASE FOR FY 1980	$27,765.2	$30,125.6	
FY 1979 supplemental estimates for R&D in FY 1980 budget		$ 830.7	
Defense		(522.7)	
NASA		(185.0)	
Energy		(23.6)	
HEW		(18.3)	
Transportation		(3.5)	
Pay raises		(77.6)	
TOTAL R&D in FY 1980 budget (OMB "Special Analysis L")	$27,765.2	$30,956.3	$32,133.7

Source: "Special Analysis P," *FY 1979 Budget*; "Special Analysis L," *FY 1980 Budget*; AAAS report *Congressional Action on Research and Development in the FY 1979 Budget*.

To summarize, if we bear in mind the impact of alternative assumptions on inflation and the fact that sizeable supplemental estimates are included in the FY 1979 totals, we can proceed with statistical analyses of the OMB budget authority totals for R&D with confidence that the statistics are close to being what they purport to be: a reasonable estimate of the total amounts for R&D in the years covered in the FY 1980 budget. We must always recognize that budget statistics by themselves tell us nothing about the need, quality, value, or relative significance of R&D. Carefully used, however, they are a useful, and perhaps the only, tool for understanding the composition and trends of federally supported R&D.

Table 5b. Adjustments Applicable to Total Estimates of R&D in the FY 1980 Budget (Budget Authority in millions).

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget
Total R&D in FY 1980 Budget (OMB "Special Analysis L")	$27,765.2	$30,956.3	$32,133.7
R&D items not included			
Post office R&D	10.8	46.0	44.4
Office of Science & Technology Policy	2.6	2.5	2.9
Office of Technology Assessment	8.7	9.4	12.5
Institute for Technological Cooperation (proposed)			25.0
AID R&D (additional identifiable)	58.0	89.5	101.8
NASA Scientific and Technical Information	25.7	24.0	27.4
TOTAL	$105.8	$171.4	$214.0
Other items not reflected			
Recommended R&D rescissions			
Energy		−$50.0	
NIH		−37.0	
NASA		− 2.4	
Supplementals for FY 1980 pay raises[1]			$80.0
TOTAL		−$89.4	$80.0
Other corrections and adjustments			
Energy (congressional reduction not reflected)		−$63.0	
NSF (carry-over adjustment)	$6.6	−16.8	
TOTAL	$6.6	−$79.8	
NET TOTAL, above adjustments	$112.4	$2.2	$294.0
ADJUSTED TOTAL R&D	$27,877.6	$30,958.5	$32,427.7

Source: *FY 1980 Budget* and agency justifications.
[1] Authors' estimate based on FY 1979 data.

C. Macroanalysis of the Totals

Now with the necessary preliminaries behind us, we will analyze the totals for R&D in the FY 1980 budget on three different bases—by character of work, by class of performer, and by major program components—and then look at what the 3-year estimates suggest is in store for the principal elements of federal R&D in FY 1981 and FY 1982.

1. Character of R&D

The classic breakdown of R&D into basic research, applied research, and development—comprising "conduct of R&D"—and a separate category for R&D facilities, has come under increasing conceptual and practical criticism in recent years, but it nevertheless provides a useful stratification of overall statistics on R&D. Table 6 gives this breakdown of the totals for budget authority already seen in Table 4.

The most noteworthy feature is the increasing trend in the support of basic research—a steady increase from FY 1978 through FY 1980, in both current and constant dollars. The FY 1980 level would be almost 24 percent above the base year FY 1972 in constant dollars—at the optimistic inflation rates assumed in the FY 1980 budget. Even with the grimmer assumption of 9 percent inflation in FY 1979 and FY 1980, the real increase over FY 1972 would be almost 20 percent, and the FY 1980 level would still be slightly above the fondly remembered peak year of FY 1967—for what comfort that may give.

For applied research and development, Table 6 shows a much slower rate of increase in current dollars, consistent with the more restrictive budget policies in these areas. This trend translates into an up-and-back-down picture from FY 1978 to FY 1980 in constant dollars at the FY 1980 budget inflation rates. At the more realistic 9 percent per year inflation rates, the decline in FY 1980 would be even more pronounced. Thus, in spite of the major continuing development efforts in defense, energy, and space, the overall levels of applied research and development activities supported by the federal government will probably decline in FY 1980 by at least 6 percent.

The facilities category is something of a wild-card in the deck and is usually ignored in discussions of trends in federal funding of R&D. Separate consideration of budget estimates for facilities and the traditional focus of attention on the "conduct" side are consistent in principle with both the standard accounting distinction between capital and operating expenses and the tendency to regard the latter as the appropriate indicator of trends of activity. Full analysis of R&D funding, however, should include comparable analyses of funds for conduct and facilities; in the case of Table 6 we would like to know how much of the $1.5 billion total in FY 1980 is going for basic research, applied research, and development facilities; or for overhead or support-type facilities whose cost should be allocated among these three categories. In the section on basic

Table 6. R&D by Character of Work (Budget Authority in billions).

	FY 1967[1] Actual	FY 1972[1] Actual	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget
Current dollars					
Basic research	$ 1.8	$ 2.1	$ 3.7	$ 4.2	$ 4.6
Applied research	2.9	3.7	5.9	6.6	7.0
TOTAL research	$ 4.7	$ 5.8	$ 9.6	$10.8	$11.6
Development	11.8	10.7	16.9	18.7	19.1
Total conduct of R&D	$16.5	$16.5	$26.5	$29.5	$30.6
Total R&D facilities	0.6	0.6	1.3	1.5	1.5
TOTAL R&D	$17.1	$17.1	$27.8	$31.0	$32.1
Constant FY 1972 dollars					
Basic research	$ 2.4	$ 2.1	$ 2.3	$ 2.5	$ 2.6
Applied research	3.9	3.7	3.8	3.9	3.9
TOTAL research	$ 6.3	$ 5.8	$ 6.1	$ 6.4	$ 6.5
Development	15.9	10.7	10.8	11.2	10.7
Total conduct of R&D	$22.3	$16.5	$16.9	$17.6	$17.1
Total R&D facilities	0.8	0.6	0.8	0.9	0.8
TOTAL R&D	$23.2	$17.1	$17.7	$18.5	$18.0

Source: "OMB Data for Special Analysis L" and *Federal Funds*, Volumes XXV and XXVII, NSF. Conversion to constant FY 1972 dollars by authors based on OMB deflators.

[1] Authors' estimates based on above sources. Estimates reflect the change in the classification of R&D in NIH.

research below, we have made an attempt to identify the amounts for facilities associated with basic research and add them to the traditional conduct-only basic research category. As far as the total amounts for R&D facilities are concerned, it is sufficient to note that the totals and trends are dominated by the requirements of the energy, defense, and space R&D programs; a breakdown by agency of the facilities totals is given subsequently in Table 16.

A final statistic—but one of doubtful significance—that can be extracted from Table 6 is the ratio of basic research to total R&D, which increases slowly but steadily over the period shown. All that this appears to mean, however, is that the decisions made on basic research have happened to increase it at a faster rate than all the separate decisions on applied research, development, and facilities have increased the total for those areas.

2. *Performers of R&D*

A full analysis of agency budgets for R&D by the types of per-

formers of R&D—government, industry, universities, and others—is usually not available until NSF publishes its annual *Federal Funds* statistics 8 or 9 months after the budget is sent to Congress, although overall statistical estimates of the total amounts to be received and provided by each sector are available earlier when the annual NSF estimates for its *National Patterns of R&D* report are prepared (see Tables A–1 and A–2 in Appendix A). This year we have been able to make our own analysis of R&D performers. We have based our analysis on budget materials for five major agencies, accounting for 88 percent of the total for conduct of R&D, and on prior year data for the remaining agencies.

Table 7 shows this analysis. In total, we see that a little over half of federal R&D funds for conduct of R&D goes for R&D in industry, a little over a quarter is for R&D activities within the federal government, and the remainder is divided about equally between amounts going to federally sponsored research centers and amounts going to colleges and universities. The trends in the totals for each type of performer parallel those in the overall total which were discussed above. The composition by performer is remarkably stable—within 0.5 percent—for the 3 years shown. The totals for colleges and universities and for industry will be discussed further in later sections.

The differing patterns of R&D performance of the five principal agencies are clearly evident in Table 7. Department of Defense R&D is noteworthy for its heavy reliance on industry; there is a small but discernible trend to reduce the proportion of funding for in-house federal R&D and to increase that going to the other sectors, especially R&D centers and colleges and universities. The Department of Energy (DOE) figures show the central role played by the former Atomic Energy Commission national laboratories and other federally sponsored nongovernment research centers. DOE trends are distorted by the omission of funds for DOE R&D facilities—almost a billion dollars, chiefly for research facilities at national laboratories and demonstration plants in industry. For NASA, the pattern is major reliance on industry combined with a large federal establishment. For the National Institutes of Health (NIH), about 60 percent of the R&D is done by colleges and universities, including medical schools, with the rest divided between in-house federal laboratories and other sectors. NSF, as would be expected, has the highest percentage of work performed by colleges and universities, almost 75 percent. The large proportion of the "other agencies" category going for R&D within the federal government reflects the historic operating patterns of old-line federal departments like Agriculture, Interior, and Commerce.

3. Major Substantive Components

A frustrating feature of statistical analyses of R&D in the budget is that the overall statistical data available generally lend themselves to aggregation only in terms such as character or performers of R&D that

give little indication of what R&D is going on or why it is being done. One usually has to jump all the way from the somewhat sterile overall statistics, like those in the preceding sections, to the detailed and fragmented data on R&D in particular agencies and programs—such as

Table 7. Federal Support for Conduct of R&D by Performer, Current Dollars (Budget Authority in millions).

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget
Defense	$(11,829)	$(13,163)	$(13,935)
Federal government	3,356	3,675	3,807
R&D centers	206	240	282
Colleges and universities	307	335	375
Industry	7,960	8,913	9,471
Energy	(4,238)	(4,679)	(4,663)
Federal government	208	224	240
R&D centers	2,476	2,697	2,707
Colleges and universities	232	238	251
Other (industry and nonprofit)	1,322	1,520	1,465
NASA	(3,875)	(4,392)	(4,540)
Federal government	1,156	1,223	1,275
R&D centers	92	118	150
Colleges and universities	130	146	151
Industry	2,453	2,857	2,915
Other (nonprofit)	44	48	49
NIH	(2,576)	(2,957)	(2,957)
Federal government	452	516	530
Colleges and universities	1,492	1,737	1,747
Other (industry and nonprofit)	632	704	680
NSF	(749)	(819)	(910)
Federal government	89	97	105
R&D centers	58	62	68
Colleges and universities	551	604	681
Other (industry and nonprofit)	51	56	56
Other agencies	(3,213)	(3,477)	(3,623)
Federal government	1,526	1,652	1,721
R&D centers	132	143	149
Colleges and universities	581	677	730
Industry and other	974	1,005	1,023
TOTAL	$(26,480)	$(29,487)	$(30,628)
Federal government	6,787	7,387	7,678
R&D centers	2,964	3,260	3,356
Colleges and universities	3,293	3,737	3,935
Industry and other	13,436	15,103	15,659

Source: Authors' estimates based on agency budget materials, "OMB Data for Special Analysis L," and *Federal Funds*, Volume XXVII, NSF.

those we shall present in the next two chapters. The NSF reports on *Federal R&D Funding by Function* and the newly initiated NSF annual *Science and Technology Report* eventually fill this gap but are not available until long after the budget is sent to Congress. The only bridge available with the budget itself has usually been the OMB figures which divide the totals for conduct of R&D into three categories: defense, space, and civilian R&D.

In Table 8, we have attempted to expand OMB's analysis of the totals for R&D in the FY 1980 budget (including R&D facilities) to show six categories of interest, which account for over 90 percent of the total. This analysis enables one to see the major programmatic components and trends of federally funded R&D. In Table 8, the detail adds to the

Table 8. Major Components of Federal Funding for R&D[a] (Budget Authority in billions).

	FY 1967 Actual	FY 1972 Actual	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget
Current dollars					
Defense[1]	$ 8.8	$ 9.2	$13.2	$14.7	$15.7
Space[2]	4.7	2.7	3.3	3.6	3.7
Civilian[3]	(3.6)	(5.2)	(11.3)	(12.7)	(12.8)
Health[4]	1.3	2.0	3.6	4.1	4.1
Energy[5]	0.6	0.6	3.7	4.1	3.9
General Science[6]	0.5	0.7	1.2	1.3	1.4
All other	1.2	1.9	2.9	3.2	3.3
TOTAL R&D	$17.1	$17.1	$27.8	$31.0	$32.1
Constant FY 1972 dollars					
Defense	$11.9	$ 9.2	$ 8.4	$ 8.8	$ 8.8
Space	6.3	2.7	2.1	2.2	2.1
Civilian	(4.9)	(5.2)	(7.2)	(7.5)	(7.1)
Health	1.7	2.0	2.3	2.4	2.3
Energy	0.8	0.6	2.3	2.4	2.2
General science	0.7	0.7	0.8	0.8	0.8
All other	1.6	1.9	1.8	1.9	1.9
TOTAL R&D	$23.2	$17.1	$17.7	$18.5	$18.0

Source: Authors' estimates based on data from Office of Management and Budget; *FY 1980 Budget;* "Special Analysis L," *FY 1980 Budget; Federal Funds,* Volumes XXV and XXVII, NSF; *An Analysis of Federal R&D Funding by Function, FY 1969–1978,* NSF. Conversion to constant FY 1972 dollars by authors based on OMB deflators.

[a] Includes conduct of R&D and R&D facilities.

[1] Includes DOD and defense activities in DOE.

[2] Includes NASA minus space applications and aeronautical research.

[3] Includes all R&D not in Defense and Space.

[4] Based on data from OMB on health research in all federal agencies. Excludes health research in DOD, DOE, NASA, and NSF.

[5] Includes DOE, Nuclear Regulatory Commission, and energy research in EPA; defense activities and general science in DOE are excluded.

[6] Includes NSF and general science in DOE.

total (except for rounding); this has both advantages and disadvantages. The advantages are those of providing a simple division of the total and a convenient basis for analysis. The disadvantages are serious and stem from the fact that there are necessary overlaps among the categories, with the result that all of the categories are understated and the trends possibly distorted. Some of the principal areas of overlap will be mentioned below, but the amounts involved have been beyond our estimating capabilities this year. The development and use of multidimensional statistics not based on mutually exclusive categories would be a much needed step for more meaningful analyses of R&D.

What does Table 8 show? The "Defense" category, which includes Department of Defense R&D and defense-related R&D in the Department of Energy but excludes the defense-related R&D of other agencies, such as NASA's space shuttle and aeronautical R&D, shows continuing increases in current dollars but a leveling off in constant dollars to a point below that of FY 1972 and substantially below FY 1967. With more inflation than is assumed by the administration, the effective total will decline in FY 1980. The "space" category includes NASA space technology and space science activities but excludes all R&D in civil space applications and the very substantial amounts of space R&D in the Department of Defense. The current dollar increase chiefly reflects the development curve of the space shuttle and some increase in space sciences; in real dollars there will be a decline. The "health" category corresponds to the OMB crosscut of health research, discussed in a later section, except that health research falling in other categories has been excluded to avoid double counting. Here we see significant real growth over the years, capped off in FY 1980 by the administration's decision to hold NIH at the FY 1979 level in the FY 1980 budget. The "energy" category comprises all energy R&D in DOE, Nuclear Regulatory Commission (NRC), and the Environmental Protection Agency (EPA). It excludes energy-related R&D in Defense and other agencies. The figures show the great increases approved through FY 1979 and the decrease in FY 1980 resulting from the administration's restraints on demonstrations and other major development programs. Our "general science" category consists only of all NSF-funded R&D and DOE general science programs, including R&D facilities in both cases; it excludes sizeable science programs in Defense, Energy, and NASA, as well as those of all other agencies.

4. Estimates for FY 1981 and FY 1982

The value of our statistical analyses of R&D in the FY 1980 budget statistics would be greatly enhanced if we could place the estimates for FY 1980 into comparable contexts that extended forward as well as backward in time. If the new emphasis on 3-year budgeting somehow would yield R&D estimates for the future years in the same detail as is now available for the budget and prior years, our macroanalysis could have

placed FY 1980 in the center of a 5-year span, and we might have almost as good an idea of where R&D is going as we now have of where it has been.

The 3-year data actually available do not pretend and probably should not be expected to approach this degree of detail. There are, however, enough data for FY 1981 and FY 1982 in the budget documents to permit fairly good estimates. We have identified 3-year estimates for items corresponding to about 88 percent of the FY 1980 total for R&D and, with some statistical manipulation, have been able to cast these estimates in a form which permits comparison of the FY 1981 and FY 1982 estimates for R&D with the amounts in the FY 1980 budget. The results are shown in Table 9 for both budget authority and outlays; we have already used the outlay figures in Chapter 1 in discussing the place of R&D in overall planning for future federal budgets.

The breakdown in Table 9 is a hybrid of agency and functional categories, determined by data availability rather than logic. The amounts for the categories of identifiable R&D other than Defense do not include allowances for future inflation and federal pay raises; these are added in separately in a single figure. Thus, the detail amounts, except for Defense, can be taken as representing the administration's intentions in constant FY 1980 dollars and the bottom line as the overall total for R&D in current dollars.

For Department of Defense R&D, the figures show an increase of 13.5 percent in FY 1981 and a leveling off in FY 1982. Both figures include an unspecified allowance for future inflation, understood to be at least 5 percent per year, in accordance with the multiyear budgeting practices which DOD has been using for several years. The figures published in the budget thus appear to call for a significant real increase in FY 1981, followed by a real decline in FY 1982 equal to the further inflation assumed for that year. As we will see later, the FY 1981 estimates have supporting detail approaching that available for FY 1980. The leveling-off figure in FY 1982 may merely reflect less complete planning for that year.

Table 9 shows that for most other estimating categories, the budget authority estimates for FY 1981 and FY 1982 are straight-line projections of the amounts approved for FY 1980, perhaps reflecting the absence of long-range budget plans and planning systems in those agencies. Thus, the fact that no increases are shown for NSF, NIH, or Agriculture does not imply a decision against future real growth but simply the absence of an approved affirmative decision for more growth. Within the overall budget totals, there are planning allowances of $4.0 billion in both FY 1981 and FY 1982 for contingencies which would permit some later decisions to increase programs above the levels now projected without increasing the overall total. R&D proponents, like all the rest, can always hope that some of these dollars may eventually come their way.

The clearest case of long-range future budget planning is offered by NASA, which has operated within a framework of multiyear budget planning since its early days. Here the published budget figures follow the declining trend resulting from the decreasing requirements of the space shuttle development program. This trend is offset in part, however, by specific allowances for a "wedge" of almost $200 million in FY 1981 and almost $500 million in FY 1982 for new projects to be started in those years. Energy R&D is another area where some explicit long-

Table 9. Amounts for R&D Included in FY 1981 and FY 1982 Estimates in the FY 1980 Budget (in millions).

	FY 1980 Budget	FY 1981 Est.	FY 1982 Est.
Budget authority			
Identifiable R&D			
Defense—RDT&E	$13,536	$15,364	$15,366
DOE—research and technology	4,743	4,772	4,597
NASA—total	4,725	4,597	4,335
HEW—health research	3,440	3,448	3,448
NSF—total	1,011	1,007	1,007
Agriculture—research	532	532	532
Institute for Technological Cooperation (proposed)	25	40	60
Other identifiable	233	233	233
TOTAL identifiable R&D	$28,245	$29,993	$29,578
All other R&D	3,889	3,900	3,900
Inflation and pay raises	—	1,265	2,236
TOTAL R&D	$32,134	$35,158	$35,714
Outlays			
Identifiable R&D			
Defense—RDT&E	$13,015	$14,633	$15,365
DOE—research and technology	4,638	4,778	4,691
NASA—total	4,595	4,602	4,421
HEW—health research	3,365	3,451	3,469
NSF—total	950	947	947
Agriculture—research	494	525	534
Institute for Technological Cooperation (proposed)	6	20	26
Other identifiable	247	233	230
TOTAL identifiable R&D	$27,310	$29,189	$29,683
All other R&D	3,854	3,850	3,850
Inflation and pay raises	—	1,256	2,249
TOTAL R&D	$31,164	$34,295	$35,782

Source: Tables in Part 5, *FY 1980 Budget*, and authors' estimates.

range planning appears in the budget figures for FY 1981 and FY 1982. Finally, we may note that the administration figures show future increases for its proposed new institute for scientific and technological cooperation up to $60 million in FY 1982.

The estimates for FY 1981 and FY 1982 have a long way to go before they have even the status of official budget recommendations to Congress. Policies and priorities may change. Inflation and the steps taken to combat it are bound to leave their marks. The estimates do, however, provide some insights into the longer-term intentions and expectations of the administration at the time that the FY 1980 budget decisions were made. The bottom line is that, except in the case of Defense R&D, the administration's long-range budget planning at that time did not call for—but did not rule out—real increases in the major categories of federal R&D in FY 1981 and FY 1982. Whether the President's later special message on science and technology will affect budget planning for FY 1981 and FY 1982 remains to be seen.

Chapter 4

R&D Budget Highlights

The full meaning of R&D policies and overall budget statistics lies in the R&D programs themselves. The programs are usually managed by individual agencies, but they often address "national needs" of broader concern. In this chapter we try to capture the highlights of R&D in the FY 1980 budget in areas of special interest and scientific disciplines. Then, in the following chapter, we will take a closer look at the budgets of the principal R&D agencies.

A. Basic Research

Table 10 shows the totals and trends in federal support of basic research in current and constant FY 1972 dollars, based on the administration's inflation assumptions, for each of the principal agencies involved. It documents the administration's intention to provide an increase of about 2 percent in constant dollars in FY 1980, continuing the real growth that began in FY 1975. The subtotal line in Table 10, which corresponds to the official scorekeeping category—the OMB conduct of basic research category used in "Special Analysis L"—shows net constant dollar increases in budget authority of 2.1 percent in FY 1980 over FY 1979 and 7.4 percent in FY 1979 over FY 1978. If the distorting effects of congressional actions and administration reactions on NIH explained below are set aside, the constant dollar increases for the other agencies average 6.1 percent for FY 1979–FY 1980 and 3.75 percent for FY 1978–FY 1979.

Before proceeding with a discussion of these data, a few comments on the statistics are in order. The allocation of agency budgets among basic research, applied research, and development is not an exact procedure. A certain arbitrariness in defining programs is inevitably involved, and the severe time pressure under which the figures are compiled compounds the problem. For example, further analysis by agency officials of

NASA estimates for basic research has resulted in a change from the $630 million reported for "Special Analysis L" and shown in Table 10, to $599 million. This and undoubtedly other changes will be reflected in the NSF statistical reports to be issued later. The basic research category is also not stable from year to year. For example, definitional changes were made by EPA and NIH in the FY 1980 budget figures. At EPA, the anticipatory program is now considered the only basic research activity. The change at NIH was a part of the Institutes' continuing efforts to develop a more useful model of budget formulation and presentation and has resulted in a greater portion of the NIH budget being classified as basic research in the FY 1980 budget. Prior year totals have not yet been officially revised; our estimates on the new basis are based on conversations with NIH officials.

A more fundamental problem relates to the universe for which data are presented. Official OMB and NSF statistics on basic research have

Table 10. Basic Research by Agency in Current and Constant FY 1972 Dollars (Budget Authority in millions).

	FY 1967[1] Actual	FY 1972[1] Actual	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget	Percent change FY 1979 to 1980
Current dollars						
HEW	$ 448	$ 626	$1268	$1558	$1575	+1.1%
(NIH)	(385)	(546)	(1156)	(1429)	(1435)	(+0.5%)
NSF	239	368	678	741	828	+11.8%
NASA	328	332	479	530	630	+18.8%
Energy[2]	302	268	441	471	549	+16.5%
Defense—Military	284	270	320	380	441	+16.3%
Agriculture	100	137	228	252	268	+6.2%
Interior[3]	—	—	157	176	174	−1.0%
Smithsonian[3]	—	—	35	37	39	+5.4%
Commerce[3]	—	—	29	32	35	+6.5%
EPA[3]	—	—	5	8	17	+113.9%
Other	103	138	26	28	31	+10.2%
SUBTOTAL	$1804	$2139	$3665	$4214	$4587	+8.8%
Additional funds for basic research						
R&D facilities						
Energy	•	•	$ 127	$ 153	$ 168	+9.8%
Other	•	•	106	136	34	−75.0%
NASA spacecraft and launch vehicles	•	•	84	161	253	+57.1%
TOTAL basic research			$3982	$4664	$5042	+8.1%

traditionally been limited to funds for the conduct of basic research—funds going to investigators and others for the performance of basic research—and have excluded funds for basic research facilities and other capital costs. Thus, the very substantial amounts for large basic research facilities, like high energy particle accelerators in DOE and radio and optical telescopes funded by NSF, have been excluded. For NASA, the large amounts for developing spacecraft for basic research missions and for procurement of the necessary launch vehicles have also been

Table 10. (*continued*)

	FY 1967[1] Actual	FY 1972[1] Actual	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget	Percent change FY 1979 to 1980
Constant FY 1972 dollars						
HEW	$ 605	$ 626	$ 859	$ 929	$ 880	−5.2%
(NIH)	(520)	(546)	(738)	(851)	(802)	(−5.8%)
NSF	323	368	433	442	463	+4.8%
NASA	443	332	305	316	352	+11.4%
Energy[2]	408	268	282	281	307	+9.2%
Defense—						
Military	384	270	204	226	247	+9.0%
Agriculture	135	137	146	150	150	−0.3%
Interior[3]	—	—	100	105	97	−7.2%
Smithsonian[3]	—	—	22	22	22	−0.9%
Commerce[3]	—	—	18	19	19	—
EPA[3]	—	—	3	5	9	+100.0%
Other	139	138	17	17	17	+3.6%
SUBTOTAL	$2437	$2139	$2338	$2511	$2564	+2.1%
Additional funds for basic research						
R&D facilities						
Energy	•	•	$ 81	$ 91	$ 94	+3.0%
Other	•	•	68	81	19	−76.6%
NASA spacecraft and launch vehicles	•	•	54	96	141	+47.3%
TOTAL basic research			$2541	$2780	$2818	+1.4%

Source: "OMB Data for Special Analysis L," *Federal Funds*, Volumes XXV and XXVII, NSF, and agency budget documents. Conversion to constant FY 1972 dollars by authors based on OMB deflators.

• Not available.

[1] Authors' estimates based on above sources. NIH estimates are comparable with the classification of R&D in NIH used in the FY 1980 budget.

[2] For FY 1967 and 1972, data are reported under the Atomic Energy Commission.

[3] For FY 1967 and 1972, this agency is included in "Other."

excluded. The result is that total federal funding for basic research has been systematically understated. The bottom line of Table 10 shows that including readily identifiable capital amounts brings total planned federal support of basic research to more than $5 billion in FY 1980.

With the above caveats in mind, let us examine the agency totals. The increase in basic research—tied as it is to a policy that assumes a major contribution by basic research to the solution of a wide range of pressing problems—is spread across many "mission" agencies. NSF does not lead the way, as was once expected, although the unique and important contributions of NSF to the basic research enterprise are emphasized in the budget documents. The largest increases for basic research in FY 1980 are in NASA (even with the adjustment noted above), Energy, Defense, and EPA.

In the case of NIH, Congress approved an extraordinary increase in FY 1979 over the budget recommendation, which translated into an increase in basic research of 23.6 percent in current dollars and 15.3 percent in constant dollars at the administration's inflation rates. The administration's reaction in the FY 1980 budget, as we have mentioned, was to accept the FY 1979 increase but to hold to the same level in current dollars for FY 1980, which means a decrease in constant dollars. Nevertheless, for the 2-year period FY 1978–FY 1980, the NIH figures show a constant dollar increase for basic research of 8.7 percent.

The trends in federal funding of basic research shown in Table 10 will be severely undercut if, as expected, actual inflation rates are significantly higher than the rates assumed in the FY 1980 budget and reflected in the constant dollar part of Table 10. If inflation turns out to be 9 percent in both FY 1979 and FY 1980 and if no supplemental budgets are provided, the average real increase from FY 1979 to FY 1980 in the traditional category, excluding NIH, would drop from 6.1 percent to 4.2 percent, and from 3.75 percent to 1.4 percent for FY 1978–FY 1979. NIH would suffer a real decline of 7.7 percent in FY 1980 (if Congress doesn't come to the rescue) but would still post a real increase of 4.5 percent over FY 1978.

While data directly related to the FY 1980 budget are not available at this writing, current NSF estimates are that about 55 percent of federally funded basic research will be performed by colleges and universities, about 10 percent by federal research centers associated with universities, about 7 percent by other nonprofit institutions, about 5 percent by industry, and about 22 percent within the federal government—a pattern that has been fairly stable in recent years.

Federal support represents about 68.5 percent of all U.S. expenditures for basic research. As shown in Table A–3 (Appendix A), the national total for basic research is estimated by NSF at about $7.4 billion in 1980. Of this total, over half is conducted at universities and colleges. Using the administration's inflation factors, all performers show real increases in 1980. Since 1972, basic research performed by industry and

by the federal government show noteworthy large real increases of 20 percent and 19 percent, respectively; academic basic research shows a real growth of 9 percent.

B. R&D at Universities and Colleges

The amounts in the FY 1980 budget estimated to go for conduct of R&D at universities and colleges are shown in Table 11. In current dollars the academic sector can expect an increase of 5.3 percent, which is a decrease in real terms, even using the administration's optimistic assumptions on inflation. Over the 3 years FY 1978 to FY 1980, the administration is expecting a 4.7 percent constant dollar increase. Again, these trends reflect primarily the R&D funding pattern of HEW (mainly NIH)—a large increase in FY 1979, and a decrease in FY 1980. From the other R&D agencies, academic R&D will get increases above the rate of

Table 11. Federal Support for Conduct of R&D at Colleges and Universities (Budget Authority in millions).

	FY 1967[1] Actual	FY 1972[1] Actual	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget	Percent change FY 1979 to 1980
HEW	$ 620	$ 916	$1707	$1968	$2001	+1.7%
(NIH)	(478)	(756)	(1492)	(1737)	(1747)	(+0.5%)
NSF	209	362	551	604	681	+12.7%
Defense—Military	280	215	307	335	375	+12.1%
Energy	90	84	232	238	251	+5.3%
Agriculture	64	88	173	209	219	+4.8%
NASA	124	119	130	146	151	+3.4%
AID	3	16	24	48	66	+37.1%
EPA	—	18	50	51	53	+4.5%
Interior	23	25	35	40	42	+5.5%
Commerce	6	24	35	39	37	−6.3%
Transportation	11	13	16	20	21	+3.0%
Other	24	22	34	39	39	−0.3%
TOTAL						
Current dollars	$1454	$1902	$3293	$3737	$3935	+5.3%
Constant FY 1972 dollars	$1964	$1902	$2101	$2227	$2200	−1.2%

Source: "OMB Data for Special Analysis L" and *Federal Funds*, Volumes XXV and XXVII, NSF. Conversion to constant FY 1972 dollars by authors based on OMB deflators.

[1] Authors' estimates based on obligation data.

inflation (even a more realistic higher rate) from the Department of Defense (DOD), NSF, and the Agency for International Development (AID); support from NASA and the Departments of Energy (DOE) and Agriculture (USDA) will lose ground because of inflation.

The picture for universities and colleges is made somewhat brighter by considering support excluded from the table. An analysis by DOE after the budget was released resulted in the addition of about $15 million to the amounts shown in "Special Analysis L." Consideration of all the ways in which academic institutions receive funds from DOE—including subcontracts with national laboratories, construction projects, and free use of research equipment—brings the DOE FY 1980 total to $574 million, but the 3-year trend remains about the same. Presumably, similar analyses by other agencies would increase the amounts shown for them in Table 11. The statistics also exclude any effects of a new government-wide emphasis on greater involvement by academia in federally supported research. Several agencies—DOE, DOD, USDA, and the National Oceanic and Atmospheric Administration (NOAA)—have stated explicitly that they are seeking ways to expand their relationships with the academic community.

Additional statistics on national expenditures for R&D at universities and colleges are included in Tables A–4 and A–5 (Appendix A). We see there that, in 1980, funds for R&D at universities and colleges from all sources are expected barely to keep pace with the optimistic estimates on inflation. About two thirds of academic R&D is supported by the federal government, and a little less than one quarter comes from universities and colleges themselves. The estimates do not show a marked increase in industry support of academic research—just enough to keep pace with inflation. Approximately 70 percent of R&D performed by colleges and universities is basic research.

The major problems facing academic science remain the growing obsolescence of equipment, the lack of opportunities in some fields for young researchers, and the administration and management of the grant process. The FY 1980 budget includes some specific attempts, particularly by NSF, at tackling the equipment problem. The increases in support for basic research are intended both to help alleviate the equipment problem and to provide increased opportunities for young scientists. OSTP and some of the agencies, most notably NSF, NIH, and DOD, are beginning to examine the nonbudget items affecting research productivity. The current attitude is probably best characterized as one of recognition of and concern for the problems, with some well-intentioned efforts at seeking solutions. Two efforts related to the administration and management of research are worth mentioning:

(1) An experiment conducted by the Chemistry Division of NSF with assistance from the Association of American Universities will try out ways to provide more flexibility for the universities and to simplify the paperwork associated with administering basic research grants. There

are two key elements in the experiment: (i) all projects approved by NSF's Chemistry Division in a single university chemistry department are included in one master grant and (ii) review and approval by the university of administrative and management details of the projects in the grant are permitted. Four schools are currently involved in the experiment, and as many as eight are expected to participate.

(2) After 4 years of intense negotiation with the academic community, OMB recently issued the new accounting procedures (referred to as Circular A–21) for federally sponsored research at universities. The new regulations are scheduled to go into effect on October 1 of this year, but it will probably be a couple of years before judgments can be made on whether the new cost-accounting principles have struck an acceptable compromise between the universities' desire for flexibility and the government's need for accountability.

C. Energy R&D

For the most part, the President's proposals in the FY 1980 budget for energy R&D follow the course he charted on taking office 2 years ago. The major deviation, which began with the President's "Sun Day Amendment" to the FY 1979 budget, is the large increase proposed for solar energy R&D. (The increases provided for solar R&D during the past 2 years have been largely the work of Congress; the administration proposed approximately level funding.) The premises on which the energy R&D proposals are based continue to be that (i) the appropriate federal role in energy R&D is to concentrate on technologies with high levels of technical risks and long development times; (ii) realistic energy prices and investment incentives should stimulate the private sector to introduce new energy technologies in the near term; and (iii) the availability of weapons-grade by-products from nuclear energy technologies should be minimized.

As shown in Table 12, total budget authority for energy R&D in the Department of Energy will remain approximately level in current dollars; this means a downward trend in constant dollars. The administration has recommended several changes in the program mix, however, as it continues to try to alter the course of R&D in DOE within a level budget by encouraging long-term, less expensive research and by being more selective about near-term, expensive development and demonstration projects. As we have mentioned in previous AAAS reports, DOE has not been able to spend increased funding in many areas at the rate it has been appropriated by Congress; this suggests that careful consideration of priorities and management procedures in DOE may be more important to energy R&D than a continuous spiral of higher budgets. It should also be noted that, even within leveled-off budget authority, actual spending (outlays) on energy R&D will continue to increase as a

Table 12. Nuclear and Non-Nuclear Energy R&D in the Department of Energy, Current Dollars (Budget Authority in millions; includes plant and capital equipment).

	FY 1979 Est.	FY 1980 Budget
Nuclear energy R&D		
Fission	$1305.4	$1243.1
Convertor reactors	(121.9)	(104.2)
Advanced nuclear systems	(54.6)	(40.3)
Breeder reactors	(741.7)	(589.9)
Commercial wastes and spent fuel	(202.1)	(219.9)
Defense waste management	(95.3)	(196.9)
Uranium resource assessment	(69.4)	(80.0)
Other	(20.4)	(11.9)
Fusion	500.1	510.0
Magnetic fusion	(356.0)	(364.1)
Inertial confinement fusion	(144.1)	(145.9)
SUBTOTAL	$1805.5	$1753.1
Non-nuclear energy R&D		
Solar	$ 441.0	$ 509.5
Fossil	759.7	747.6
Conservation	235.2	238.9
Geothermal	158.0	140.9
Biomass	43.0	57.8
Hydropower	28.4	18.5
Electric energy systems and storage	100.7	93.9
SUBTOTAL	$1766.0	$1807.1
TOTAL energy R&D	$3571.5	$3560.2

Source: Agency budget justification.

result of the large increases in DOE appropriations in recent years. Even in this year of budget restraint, however, Congress may not support the level budget authority proposed if key members continue to regard large energy development and demonstration projects as a source of political leverage with the folks back home.

Total energy R&D is divided about equally between nuclear and non-nuclear energy R&D. Nuclear energy R&D decreases slightly; non-nuclear increases slightly. The nuclear fission programs are reoriented considerably in support of the administration's nonproliferation policies. Increased emphasis is placed on waste management and the assessment of uranium resources. Overall, funds for fission technology decrease as efforts are directed toward the study and development of a new generation of nuclear technologies to reduce proliferation risk. The light water reactor is the only technology in the present generation of fission systems to receive an increase in the FY 1980 budget. No funds

are requested for the Clinch River breeder reactor project or the steam cycle, high temperature gas cooled reactor (HTGR); however, funds are requested for a joint R&D program with the Federal Republic of Germany on the direct cycle HTGR. The conflict between the administration and the Congress over the Clinch River project continues. Currently, the administration is required to spend the $172.4 million on Clinch River as appropriated by Congress. The decision whether to spend this money for Clinch River or some alternative was supposed to have been made in the FY 1979 DOE authorizing legislation, which never came to a final vote. For FY 1980, the administration again proposes to terminate Clinch River, but does plan to support a general R&D program on liquid metal fast breeder reactor technology.

In non-nuclear energy R&D, solar and biomass programs receive substantial increases, and both are considered as solar technology in the budget documents. Solar technology is the only area of energy technology for which a large overall increase is proposed in the FY 1980 budget, and solar thermal systems and photovoltaics receive special emphasis. Moreover, additional solar energy proposals may soon be forthcoming. In conjunction with "Sun Day" last spring, President Carter commissioned a domestic policy review on solar energy that was completed too late to influence the FY 1980 budget but may be the basis for a presidential message or supplemental budget request. The other non-nuclear programs decrease or remain at about the FY 1979 level. The rapid growth over the last several years in geothermal and conservation activities is cited as the rationale for the no-growth policy in these areas in FY 1980.

The decrease in fossil energy R&D is attributed to increased attention to long-term R&D and greater reliance on the private sector for near-term efforts and large demonstration projects. Two examples in the coal program are illustrative of the harder line taken in the budget on demonstration projects. First, the administration is proposing a rescission of funds in FY 1979 for the construction of a third low/medium BTU coal gasification demonstration plant. Second, no construction funds are requested in FY 1980 for the Solvent Refined Coal Demonstration Program. In FY 1979 Congress appropriated funds for two plants; one to convert coal to a clean solid, the other to convert coal to a clean liquid. At budget time, the administration plan was to proceed with feasibility studies on both plants, but to select only one for the demonstration phase; funds from the terminated project would be reprogrammed for use in the surviving project. As we go to press, however, there is speculation that the President will approve both plants in response to pressure from Congress and as an example of positive government action during the current "episode" in our energy crisis. Increases in the coal program are requested for advanced research and technology development, flue gas desulfurization and other environmental control systems, and a high-BTU coal gasification demonstration plant.

D. Health Research

Table 13, for which data are available only in terms of outlays, shows that the totals for health research are expected to increase by 10.6 percent to $4.4 billion in FY 1980. The federal government provides approximately two-thirds of the total national investment in health research. NIH, in turn, accounts for about two-thirds of these federal funds and over 85 percent of HEW's health research budget. It is not surprising, therefore, that the level budget authority proposed for NIH in the FY 1980 budget is the major concern of those interested in health research policy. As Table 13 shows, however, actual spending (outlays) by NIH will increase by 10.4 percent in FY 1980 as a result of the large increases in NIH budget authority in recent years, particularly FY 1979. This is the rationale espoused by the administration for the proposed level funding, but anticipation of another congressional increase might also have been a factor. Congressional acceptance of the President's FY 1980 request would significantly affect funding patterns at NIH, as will be seen when we discuss HEW R&D in the next chapter.

The one component of the federal health research establishment to receive a sizeable increase is the research budget for the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA), reflecting the recommendations of the President's Commission on Mental Health. In FY 1980, outlays will increase by 15.1 percent to a total of $229 million as a result of the 45.2 percent ($73.3 million) increase in budget authority

Table 13. Health Research in the FY 1980 Budget by Agency (Outlays in millions).

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget
HEW	$2920	$3131	$3473
(NIH)	(2505)	(2681)	(2961)
Energy	201	208	220
Defense	129	135	145
Agriculture	91	113	132
Veterans	121	128	127
EPA	61	71	77
NSF	60	67	74
Interior	40	53	67
NASA	44	39	51
Transportation	5	5	5
Labor	2	4	4
State	4	4	4
Justice	1	1	1
Other agencies	34	45	47
TOTAL health research	$3713	$4004	$4427

Source: OMB data for Chapter 5, *FY 1980 Budget.*

for research at ADAMHA in the 2 years since the Commission began its work. Other increases include assessments of health care technologies in HEW, human nutrition research in the Department of Agriculture, health and environmental research at DOE, and research on toxic substances at EPA.

The health effects of toxic substances have been receiving special attention from federal R&D policy-makers, budgeteers, and managers, and they are likely to be the focus of growing concern. One loosely organized effort connected with the preparation of the FY 1980 budget was an "interagency zero-base budgeting" exercise on toxic substances research. Seven agencies—National Cancer Institute (NCI), National Institute for Environmental Health Sciences (NIEHS), National Institute for Occupational Safety and Health (NIOSH), Food and Drug Administration (FDA), Consumer Product Safety Commission (CPSC), Occupational Safety and Health Administration (OSHA), and EPA—participated. There were no budget trade-offs, but EPA did get additional money from within its own budget ceiling for research, and NCI will spend $15 million of its budget on areas of interest to EPA. The principal outcome, however, appeared to be a recognition that with improvement the process may help to integrate federal activities in this area. A major initiative in FY 1979 is the establishment of a National Toxicology Program in HEW to improve the testing of chemicals of public health concern and to develop and validate new and better integrated test methods. A total of $41 million is being provided for this undertaking with reprogrammed money from the four participating agencies (NCI, $21 million; NIEHS, $11 million; FDA, $7 million; NIOSH, $2 million). The FY 1980 budgets for these agencies include the same amounts for the program, and administration officials hope to convince additional agencies to participate; for example, the other three agencies that took part in the interagency budget exercise.

All of HEW's health research is now the subject of a process aimed at developing a 5-year research plan and budget. The process, initiated at the personal request of the Secretary of HEW, began last summer with the drafting of a set of "research principles" by HEW, primarily NIH. At this writing, the principles have been reviewed by the scientific community, including a special committee of the Institute of Medicine, and are now back at HEW awaiting further action. According to the Secretary's original plan, the principles will now be the basis for specifying research goals; the goals in turn will be translated into "a concrete five-year budget" by the fall of 1979; and then we "will know exactly what [HEW's] thinking is for the next five years." The entire exercise has been severely criticized by the scientific community, and it seems unlikely that the 5-year plan for health research will be a reality by the fall.

E. Environmental R&D

Support for environmental R&D is a significant portion of federally supported civilian R&D. As shown in Table 14, some sixteen agencies are requesting nearly $2.4 billion in FY 1980 for environmental R&D, a 10.4 percent increase over FY 1979. Looking at the total allocated according to function, we see that in FY 1980 environmental studies will be divided approximately equally between (i) identification, control, and monitoring pollutants, and (ii) understanding ecological systems and environmental interactions. Control and abatement are the big growth

Table 14. Environmental R&D in the FY 1980 Budget (Budget Authority in millions).

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget
By function			
Pollution control and abatement	$ 960	$ 965	$1111
Understanding, describing, and predicting	1110	1203	1282
Locating and describing natural resources	(282)	(331)	(335)
Environmental impact on humans	(280)	(310)	(319)
Observing and predicting weather, ocean conditions, and disturbances	(254)	(265)	(302)
Ecological and other basic research	(248)	(261)	(287)
Physical environment surveys	(28)	(21)	(20)
Weather modification	(18)	(15)	(19)
TOTAL	$2070	$2168	$2393
By agency			
Energy	$ 329	$ 335	$ 440
EPA	379	396	437
NASA	278	303	337
Interior	277	278	288
HEW	244	273	276
NSF	172	172	188
Agriculture	119	122	119
Commerce	95	109	119
Defense—Military	59	68	58
Transportation	50	43	55
Labor	24	27	27
Defense—Civil	16	15	19
Smithsonian	12	12	14
Nuclear Regulatory Commission	6	9	10
TVA	10	6	6
HUD	*	*	—
TOTAL	$2070	$2168	$2393

Source: "Special Analysis K," *FY 1980 Budget* and Office of Management and Budget.
* Less than $0.5 million.

areas in FY 1980; the understanding, describing, and predicting activities receive cost of living increases.

The Department of Energy, NASA, and EPA are scheduled to receive particularly large increases for their environmental R&D activities. The expansion of DOE programs on the environmental impacts of energy technologies has allowed EPA to decrease its energy R&D program. The increase in NASA is for the use of aerospace technology in monitoring and controlling pollution, and for locating and describing natural phenomena and natural resources. A "public health initiative" is the basis for EPA's increase. EPA officials report that zero-base budgeting had a marked impact on their budget again this year. In response to low rankings for research by EPA's managers of regulatory programs, the research activities were reformed to be of more practical use to them. Now research is receiving higher rankings, according to these officials, and thus the sizeable increase for R&D in the FY 1980 budget. Interestingly, this reassessment and redirection of R&D in EPA may have had implications beyond the agency, as it is for precisely this reason—that is, the increasing tendency for federally supported environmental R&D to be directed at specific program needs and regulations—that NSF increased its exploratory research related to the environment.

F. Interagency R&D Programs

This year, as in the previous two, OMB has singled out in "Special Analysis L" some R&D programs included in the budget that involve more than one agency. We describe below the two new interagency R&D initiatives, microelectronics research and crop condition assessment and forecasting. Also described are cooperative activities in climate and earthquake research, which were the principal interagency R&D initiatives in the FY 1979 and FY 1978 budgets, respectively.

1. Microelectronics and Submicron Science and Technology

Approximately $41 million in FY 1980 will support complementary efforts in DOD ($31.5 million), NSF ($8.0 million), and the National Bureau of Standards (NBS, $1.5 million) in the field of microelectronics and submicron science and technology. The DOD program is a new effort begun in FY 1979 on the development of very high speed integrated circuits that are deemed necessary for defense systems. Because of the relatively small market for the integrated circuits that DOD needs, it is felt that the commercial sector will not meet the demand. The $8.0 million provided by NSF is a $3.8 million increase over the FY 1979 level. Emphasis is on long-term, fundamental research on the properties of microstructures. Through support of university research in this area, NSF hopes to provide relevant training and experience for persons who

Table 15. National Climate Program (Budget Authority in millions).

	FY 1979 Est.	FY 1980 Budget
Climate process research		
NSF	$12.7	$13.3
Commerce/NOAA	4.8	8.7
Energy	2.1	4.3
Interior/USGS	0.8	0.9
Defense	0.7	0.8
Agriculture	0.1	0.1
TOTAL, research	$21.2	$28.1
Other program activities		
Impact assessment	$ 6.8	$ 7.6
Diagnosis and projection	9.1	10.3
Data management	11.8	13.0
Observations	29.2	53.4
TOTAL Climate Program	$78.1	$112.4

Source: "Annual Report to Congress on the National Climate Program," National Climate Program Office, NOAA (March 1979).

wish to move into this expanding industry. The funds in NBS support an ongoing program in measurement technology and physical reference standards. As is subsequently discussed in the section on "electrotechnology," this three-agency program is only a small part of the total federal effort in electronics.

2. *Crop Condition Assessment and Forecasting*

Five agencies—NASA, AID, and the Departments of Agriculture, Commerce, and Interior—will increase funding from $18 million in FY 1979 to $29 million in FY 1980 for studies on the use of space remote-sensing for obtaining early quantitative estimates of the effect of natural disasters on crop conditions and for improving worldwide agricultural production forecasting capabilities.

3. *The National Climate Program*

The President's FY 1979 budget included a request for additional funds for climate-related activities in eight agencies. Congress appropriated the funds requested and also passed the National Climate Program Act. The Act created a framework, centered around the National Climate Program Office in the National Oceanic and Atmospheric Administration, for managing the interagency climate program and also added some activities to the administration's initial proposal.

The administration's FY 1980 request for the National Climate Program is shown in Table 15. Funds for research will increase by 32.5 percent. Significant increases are provided for an advanced computer at the NOAA Geophysical Fluid Dynamic Laboratory to accelerate climate modeling efforts and for activities at DOE and NOAA aimed at understanding the processes that influence the amounts of CO_2 in the atmosphere. NASA's climate research activities are included in the total for the observational program which the research supports. NASA is the principal agency involved in observation activities; it will provide $34.7 million in FY 1980 for the development of the earth radiation budget experiment, the halogen occultation experiment, and associated research.

The administration request does not include funds for intergovernmental research and services nor experimental climate forecast centers—two activities included in the National Climate Program as approved by Congress.

4. Earthquake Research

The earthquake research program, involving NSF and the U.S. Geological Survey (USGS), is proposed to go forward in FY 1980 at a level of $52 million, well below the $62 million proposed in the FY 1979 budget. Both NSF and USGS are responsible for fundamental earthquake studies. Earthquake prediction, hazards assessment, and earthquake prevention are the responsibility of USGS; earthquake engineering and policy research and analysis are the responsibility of NSF. Future coordination of earthquake hazards reduction activities will be the responsibility of the new Federal Emergency Management Agency.

G. Competitive Grants for Agriculture Research

The FY 1980 budget continues the administration's practice of emphasizing an increase in the Department of Agriculture's competitive grants program for basic research in areas related to food production and human nutrition. For the past 3 years, the administration has proposed $30.0 million for the program, and Congress has appropriated $15.0 million. Table B–12 (Appendix B) shows that $30.0 million is requested again for FY 1980—$21.0 million for plant science research targeted to crop production, including research on nitrogen fixation, genetics, photosynthetics, and plant pests, and $9.0 million for human nutrition research.

In the past, the request for additional funds for the grants program has suffered from the perception that it was being paid for by cutbacks in the politically popular formula grants to Agricultural Experiment Stations. This year the administration hopes to avoid such a confrontation.

First, as shown in Table B–12, the formula grants program is not decreased, but remains level, which may or may not satisfy the Experiment Station proponents. Second, and probably more important, experience in the competitive grants program shows that the demand is great (as indicated by the number of proposals received) and that the current awards are distributed about equally between Agricultural Experiment Stations and science departments at land-grant institutions and other universities. After 4 years it finally may be possible to go beyond the rhetoric that a mixed strategy for agricultural research is necessary—which everyone seems to support—and move closer to an agreement on the funds and emphasis that each component should receive.

H. Disciplinary Highlights

Immediately after the release of the President's FY 1980 budget, AAAS and eleven other organizations cooperated in the preparation of an early report on the support proposed for R&D in the budget.[1] Several societies prepared summaries of support for R&D in disciplines of special interest to their members. The information presented in the following "disciplinary highlights" is taken from these analyses. Some data on specific agency programs mentioned here can be found in the tables on agency budgets in Chapter 5 and in Appendix B.

1. Social and Behavioral Research

Support for social and behavioral research in the FY 1980 budget is estimated to be $1 billion, about a 9 percent increase over the FY 1979 level. The major contributors to this total are HEW, particularly ADAMHA, and Defense, NSF, and Agriculture; sixteen additional agencies each will support more than $1 million of social and behavioral research in FY 1980.

The increase in mental health, drug abuse, and alcoholism research at ADAMHA has been mentioned previously. Some important features of additional identifiable social and behavioral R&D programs are the following:

(1) Two exceptions to the tight overall NIH budget are increases in population research and behavioral aspects of disease prevention.

(2) DOD is second only to HEW in the amount of funds provided for social and behavioral research. Most of this research is related in

[1] *Intersociety Preliminary Analysis of R&D in the FY 1980 Budget*, February 1979, American Association for the Advancement of Science, Association of American Universities, American Chemical Society, American Educational Research Association, American Institute of Aeronautics and Astronautics, American Institute of Biological Sciences, American Institute of Chemical Engineers, American Psychological Association, American Sociological Association, American Society of Mechanical Engineers, Institute of Electrical and Electronics Engineers, National Association of State Universities and Land-Grant Colleges.

some way to the all-volunteer forces. In FY 1980, about $118 million will go toward research in four areas: human factors, personnel and manpower, education and training, and simulation and training devices. Basic research will remain level, while applied research and development will increase to meet the immediate needs imposed by the changing characteristics of military personnel.

(3) Within the NSF basic science programs, behavioral and neural sciences, and social sciences lose ground to inflation, increasing by 8.5 and 5.5 percent, respectively. To explain these small increases, NSF cites the large increases in these programs over the past 3 years, the increased emphasis by NIH on support for the behavioral sciences, and the emphasis in this year's budget on environmental sciences and instrumentation. Applied social and behavioral research in NSF also receives only a small increase—$0.2 million, to a total of $9.2 million in FY 1980.

(4) In the Department of Agriculture, research on the social and behavioral factors affecting food choice will be expanded as part of the increase in competitive grants for human nutrition research.

(5) Social science research related to energy receives strong endorsement in a report by an OSTP working group on basic research in DOE. The report is critical of DOE's emphasis on only technological obstacles to new energy systems and the lack of attention to equally important social, political, and economic factors. The working group recommended that a separate program and research budget for the social sciences be established in the Office of Energy Research. There is no indication in the FY 1980 budget that this recommendation is being implemented.

2. *Education R&D*

The intersociety report estimates that support for education R&D in HEW and NSF will total $162 million in FY 1980, up slightly over the FY 1979 level of $153 million. Science education R&D at NSF will increase from $11.7 million to $15.3 million. Areas to be emphasized include basic studies of how science and mathematics are learned, updating instructional materials and methods for the early adolescent, and increasing scientific literacy of all citizens. Although the total budget for the National Institute of Education (NIE) remains approximately level, NIE officials have stated that there will be $13 million available for new initiatives. The FY 1980 program will address two major questions: (i) How do we best raise levels of literacy? and (ii) What makes a school good? The Institute will continue to follow the policies enacted last year by the National Council on Educational Research (the NIE policy-making body) requiring NIE to use at least 20 percent of its budget for fundamental research and 3 to 5 percent to support unsolicited proposals. The Office of Education will increase funding for research on bilingual education; most of the other education R&D programs in HEW remain level.

3. Physics Research

The chapter on physics in the intersociety report includes an analysis of the funds requested for physics research in NSF, DOE, and DOD. It is estimated that support for physics requested by these three agencies will total $1.1 billion in FY 1980, which is about 8 percent higher than the FY 1979 level and thus just keeps pace with inflation. Within this approximately constant overall level of effort, however, major changes are proposed in some areas.

NSF supports research in a broad range of subfields of physics through two divisions—Physics and Materials Research. All the subfields increase at about the inflation rate, with low energy (atomic and solid state) physics faring slightly better than higher energy physics, reflecting the increased effort in microstructures research, the completion of the Cornell Electron Storage Ring, and the transfer of the construction of the Michigan State Phase II heavy ion cyclotron to the Department of Energy. There is actually a small real increase in support for individual research projects in higher energy physics. As part of the agency-wide emphasis on research instrumentation and equipment, there is a substantial increase requested for the Stanford Positron-Electron Accelerator Ring (SPEAR).

The Department of Energy, continuing the practices of its predecessor agencies—the Atomic Energy Commission and Energy Research and Development Administration—is the principal source of federal funds for high energy and nuclear physics. Research in these subfields requires large, expensive high technology facilities that periodically place heavy burdens on the budget. In an attempt to minimize these budget fluctuations in the high energy physics program, DOE and the high energy physics community agreed to a "treaty" last year that "provides for a near constant level of effort over the next few years." The effort includes continued funding for the ISABELLE and energy saver projects and maintenance of the three national accelerator centers at Brookhaven, Fermilab, and Stanford. The 10 percent increase requested for high energy physics in FY 1980 is described in the intersociety report as including "considerable ebb and flow, most of it reflecting the passing of yesteryear's accelerators (zero-gradient synchrotron), the birth of today's (positron-electron colliding beam), and the gestation of tomorrow's (ISABELLE and the energy saver)." In the nuclear physics program, heavy ion nuclear physics and nuclear theory are scheduled to keep pace with inflation in FY 1980; medium energy nuclear physics will increase by about 18 percent due principally to additional construction funds for the Bates Accelerator and the Clinton P. Anderson Meson Physics Facility at Los Alamos (LAMPF).

DOE also supports research in low energy nuclear physics, solid state physics, and, through the magnetic and inertial confinement fusion programs, plasma physics. Among these subfields, the noteworthy

change is in applied plasma physics, which receives a 15.8 percent increase within a total magnetic fusion program that increases by only 2.3 percent.

The Defense Department is requesting $79.4 million for physics, astronomy, and astrophysics research in FY 1980. Although comparable figures for FY 1979 are not available, the amount is said to be at least 17 percent greater than the FY 1979 level.

4. R&D in Chemistry and Chemical Engineering

Of interest to chemists and chemical engineers in the President's FY 1980 budget is an estimated $2.5 billion for R&D spread among six agencies—NSF, Energy, EPA, Agriculture, NIH, and DOD (research only; excluding development). Large increases are proposed for chemistry and chemical engineering in NSF and for basic chemical research in DOD. In total, chemistry and chemical engineering in DOE will keep pace with inflation, and the programs in EPA, Agriculture, and NIH will remain at about the FY 1979 level. Some of the highlights of the agency proposals are

(1) Chemistry and chemical engineering enjoy a banner year in NSF, showing an overall increase of 15.9 percent (includes chemistry programs in all three of the basic science directorates). The tone is set by the opening statement in the chemistry section of the NSF budget book: "Chemistry today is enjoying one of the most exciting periods of its existence." Special emphasis will be given to lasers, catalysis, microstructures, environmental problems, and instrumentation.

(2) In DOE, chemical R&D follows the pattern of all energy R&D, with large increases proposed for basic chemical research and R&D related to solar energy and nuclear waste management. Of special interest to chemical engineers is the increase from $7.0 million to $43.3 million for the development of new technologies for burning coal to meet environmental standards.

(3) Anticipatory (long-term) research in EPA increases by 79 percent to $16.9 million. Included in this program are funds for expanded work in atmospheric chemistry and for the study of chemical processes that are involved in the exchange of pollutants from one medium to another.

(4) Trends in three programs in the Department of Agriculture that might be of interest to the chemical community are (i) funds for the Agricultural Experiment Stations supported under the Hatch Act remain at the FY 1979 level; (ii) the $15 million increase in the competitive grants program includes $11 million for research on nitrogen fixation, plant genetics, photosynthesis, and plant pests, bringing the total for these areas to $21 million; and (iii) processing, storage, and distribution efficiency research in the Agricultural Research Service is reduced by $11.1 million.

5. Biological Research

Insufficient data were available when the intersociety report was prepared, so the chapter on biology does not contain an estimate of the total amount of federal support for biological research. The chapter does illustrate, however, the breadth of federally supported research of interest to biologists; activities in six agencies are described—NSF, EPA, Agriculture, Energy, NIH, and NASA. In addition, DOD also supports research in the biological and medical sciences.

The totals and trends for some of these activities are

(1) Support for the two principal divisions in NSF that provide funds for biologists—Physiology, Cellular, and Molecular Biology and Environmental Biology—is scheduled to increase by 12.4 percent and 15.4 percent, respectively.

(2) As part of the public health initiative in EPA, there will be increased emphasis on the health effects of environmental pollution and the control of toxic substances.

(3) The programs in the Department of Agriculture mentioned in the previous section should also be of interest to biologists. In addition, competitive grants for human nutrition research will increase from $5 million to $9 million.

(4) In DOE, environmental R&D increases by 11.8 percent; basic research in the life and biomedical sciences increases by only 3.4 percent.

(5) Life sciences research in NASA increases by 9.5 percent.

(6) In FY 1980, the Department of Defense will provide $46.6 million for basic biological and medical research.

6. R&D in Electrotechnology

Total federal funding for electrotechnology R&D in FY 1980 is estimated in the intersociety report to be $4.8 billion, a 14 percent increase over the FY 1979 level. Almost 90 percent of the funding in this area is provided by DOD; relevant activities are also supported by NASA, DOE, NIH, and NSF.

Most federally funded electrotechnology R&D is in electronics. DOD and NASA support the development of a variety of electronic devices and systems to meet the technological demands of the defense and space programs. Areas of high current interest in DOD include lasers and particle beams, high speed integrated circuits, and intelligence and communications systems. In FY 1980, DOD will provide $51.9 million for basic research in electronics. NIH and NSF also support basic research in electrotechnology. At NIH, a biotechnology research program supports the development of innovative instruments and technologies for biomedical applications, including the development of applications of artificial intelligence in medicine. NSF supports computer research and electrical sciences and analysis. In the latter area, the emphasis in FY 1980 will be on large-scale integrated circuit electronics, integrated optics, optical communications, automation, and robotics.

Chapter 5

Agency R&D Trends

We will now look at R&D in the federal budget in terms of the agencies that perform the work. First we will present a summary table giving the agency breakdown of the R&D totals used in our macroanalyses. Then we will discuss briefly the R&D activities of each of almost a dozen of the principal R&D agencies. Detailed statistical tables on R&D in these agencies are included in the text or in Appendix B. We should note that the amounts in these tables often do not correspond to the amounts in the summary table; this reflects the fact that R&D in many cases is not managed or budgeted by the agencies under the same category headings as those used by OMB and NSF for statistical purposes.

A. Agency Totals

The composition by agency of the OMB totals for conduct of R&D and R&D facilities is shown in Table 16. Adjustments and corrections that might be made to these amounts and additional agencies and categories of R&D support that might be included have been discussed in Chapter 3 but are not reflected in Table 16, where the amounts shown are taken directly from the budget authority data compiled by OMB for "Special Analysis L."

What do all these figures show? To separate real trends from the effects of inflation, one should probably take 9 percent as a realistic forecast of the FY 1979–FY 1980 inflation rate. Under this assumption, increases above 9 percent would be considered "real," anything less than about a 7 percent increase would be a "real" cut, and increases between 7 and 9 percent would be regarded as "level." On this basis, we see from Table 16 that the totals for both conduct of R&D and R&D facilities decrease in real terms. In conduct of R&D, NSF is the only major R&D agency to receive a real increase; EPA remains about level, and all of the other major agencies decline in real terms. There are, however, large

real increases in R&D for some of the smaller agencies—NRC, AID, and the Corps of Engineers.

Thus, the agency R&D totals generally reflect the "lean and austere" theme of the President's budget. Within the totals, however, there are significant program and policy adjustments that are described in the following sections.

B. R&D in the Department of Defense

The most comprehensive unclassified description of R&D in the Department of Defense is the statement by Undersecretary of Defense for Research and Engineering, William J. Perry, prepared for his congressional testimony on the DOD authorization and appropriation requests. At the outset the statement indicates that the DOD posture for "Research, Development, and Acquisition" continues to be based on the in-

Table 16. Research and Development in the FY 1980 Budget by Agency, Current Dollars (Budget Authority in millions).

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget	Percent change FY 1979 to 1980
Total conduct of R&D	$26,480	$29,487*	$30,628	+3.9%
Total R&D facilities	1,285	1,469	1,505	+2.4%
TOTAL R&D	$27,765	$30,956*	$32,133	+3.8%
Conduct of R&D				
Defense—Military	$11,829	$13,163*	$13,935	+5.9%
Energy	4,238	4,679*	4,663	−0.3%
NASA	3,876	4,392*	4,540	+3.4%
HEW	3,212	3,630*	3,694	+1.8%
(NIH)	(2,576)	(2,956)	(2,958)	(+0.1%)
NSF	749	819	910	+11.1%
Agriculture	608	667	664	−0.5%
EPA	379	400	436	+9.1%
Interior	355	390	378	−3.1%
Transportation	353	354*	355	+0.3%
Commerce	277	315	328	+4.2%
Nuclear Regulatory Commission	137	160	183	+13.9%
Veterans	111	123	123	—
Labor	103	98	99	+1.0%
AID	48	68	93	+37.0%
HUD	51	57	51	−9.9%
Justice	40	42	44	+4.5%
Smithsonian	35	37	39	+5.4%

Table 16. (*continued*)

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget	Percent change FY 1979 to 1980
Corps of Engineers	$ 27	$ 26	$ 29	+14.8%
TVA	16	25	24	−4.8%
Treasury	11	11	12	+6.3%
Consumer Product Safety Commission	5	9	6	−28.2%
Library of Congress	5	5	5	+3.9%
Personnel Management	4	5	5	+17.8%
ACDA	4	4	4	+13.5%
FCC	3	3	3	—
State	3	3	2	−26.9%
Advisory Commission on Intergovernmental Relations	2	2	2	—
FTC	1	1	1	—
Federal Preparedness	1	0	0	—
TOTAL conduct of R&D	$26,480	$29,487*	$30,628	+3.9%
R&D facilities				
Energy	$ 815	$ 864	$ 936	+8.3%
Defense—Military	115	238	293	+23.1%
NASA	162	148	158	+6.8%
Transportation	20	14	26	+89.8%
HEW	86	94	25	−73.2%
(NIH)	(83)	(86)	(21)	(−75.6%)
NSF	40	38	24	−37.5%
TVA	3	13	15	+12.8%
Agriculture	25	52	13	−74.8%
Veterans	4	0	10	—
Consumer Product Safety Commission	3	3	3	—
EPA	0	1	1	+27.3%
Interior	8	4	1	−82.5%
Commerce	4	1	1	+20.0%
Smithsonian	#	#	#	+100.0%
Treasury	0	#	#	—
TOTAL R&D facilities	$ 1,285	$ 1,469	$ 1,505	+2.4%
TOTAL R&D	$27,765	$30,956*	$32,133	+3.8%

Source: "OMB Data for Special Analysis L."

Less than $0.5 million.

* FY 1979 amounts include FY 1979 supplemental estimates recommended in the FY 1980 budget totaling $831 million, as follows (in millions): Defense, $523; Energy, $24; NASA, $185; HEW, $18; Transportation, $4; and federal pay raises not distributed by agency, $77.

creasing challenge to our superiority by the Soviet Union and on a strategy to meet that challenge consisting of (i) concentration on those technologies that have the greatest potential of multiplying the effectiveness of our forces, (ii) exploitation of our industrial base, and (iii) cooperation with our allies. Dr. Perry goes on to discuss the barriers to implementing this strategy and the management techniques planned for overcoming them. The emphasis on management reflects the fact that improved management was one of the objectives in combining responsibilities for R&D and systems acquisition under one top DOD official. The management issue, moreover, has surfaced recently as a budget issue among those in Congress who cite the large backlog of unobligated funds in DOD as a basis for cutting back on the President's proposed 3 percent increase in Defense spending.

The bulk of Dr. Perry's statement consists of justifications for the research, development, test, and evaluation (RDT&E) and procurement budgets of DOD. The following discussion is based on this material.

Table B–1 (Appendix B) shows breakdowns of the RDT&E budgets of DOD by mission, military department, budget activity, and performer for FY 1978 through FY 1981. For FY 1980, $13.5 billion is requested for Defense R&D, a 6.0 percent increase over FY 1979, assuming that the $523 million for Defense R&D in the supplemental request for FY 1979 is approved. A further increase of 11.3 percent is projected for FY 1981. Our discussion will focus on the Science and Technology Program, which includes the RDT&E missions of technology base (research and exploratory development), advanced technology development (part of advanced development), and a small activity in manufacturing technology funded primarily from procurement funds. The RDT&E portion of the Science and Technology Program is proposed to increase by 16.1 percent in FY 1980 and 12.0 percent in FY 1981.

The justification for these large increases centers around the technological arms race with the Soviets. Dr. Perry estimates that the Soviet Union's science and technology program in defense is funded at about twice the U.S. level and that the Soviets are concentrating their efforts on several new technologies. The conclusion, repeated often throughout the posture statement, is that a significant increase in DOD's Science and Technology Program is essential both to maintain our present technological lead and to ensure that we are not the victims of any "technological surprises" by the Soviets.

The Science and Technology Program for FY 1980 is guided by four goals. The first two are continuations of policies included in the last four DOD budgets—10 percent real growth in research and 5 percent real growth in exploratory development. The other two, concerned more directly with weapons technologies, are (i) to expedite technologies that have promise for introducing "revolutionary" advances into the military forces and (ii) to shorten the time required to deliver advanced technology weapons to forces in the field. Some of the technologies re-

ceiving top priority are precision guided weapons, very high speed integrated circuits, insensitive explosives, and high energy lasers.

As seen in Table B–1, the President's proposed budget for DOD research exceeds the goal; in current dollars the increase is 20.3 percent, which translates to a real increase of over 11 percent if a 9 percent inflation rate is assumed. Areas to be emphasized include the synthesis of new materials and better characterization of existing materials, study of the oceans and atmosphere as emerging combat environments, determination of fundamental physical limits, and microelectronics.

Two reports published during the past 3 years have contributed to the changing environment for Defense research. The first, prepared in 1976 by a Defense Science Board study group, was *Fundamental Research in Universities.* It was a spur to the policies for real growth in research and exploratory development, and it focused attention on the role of universities in DOD research. Currently, about 45 percent of the funds in the DOD research category goes to universities, and the Department is continuing to try to enhance its relationships with academia. Last summer an OSTP working group prepared a report entitled *Basic Research in the Department of Defense*, which blesses rather than redresses many of the current policies and practices. Among areas where it does recommend changes is the management of basic research. In line with one of these recommendations, a senior DOD official has been appointed to provide broad oversight for the basic research programs in the three military services and the Defense Advanced Research Projects Agency. One of the results of this appointment is a more comprehensive picture of the research program, showing breakdowns of the funds by discipline. Although the available data are sparse at this writing, we present them in Tables B–2 and B–3 (Appendix B) to provide some illumination of a major segment of federal research which has generally been regarded by outsiders as a black box.

Table B–2 shows by discipline the FY 1979 budgets for extramural research in the principal basic research organizations in the three military services and indicates those areas scheduled for large increases in FY 1980. According to DOD, totals by discipline for FY 1980 are not shown because they will depend on the quality of proposals received in each area. In contrast to NSF, the DOD basic research program is not budgeted by discipline, but instead responds to "proposal pressure."

The services have not been using uniform categories or definitions in dividing their budgets by discipline. Table B–3 is a first attempt at obtaining such comparable data. DOD officials are quick to point out the severe limitations of these data, however, for the reasons stated above.

C. R&D in the Department of Energy

The major R&D components in the Department of Energy budget

Table 17. Major R&D Components of the Department of Energy Budget (Budget Authority in millions; includes plant and capital equipment).

	FY 1979 Est.	FY 1980 Budget
Nuclear energy R&D	$1805.5	$1753.1
Fission	(1305.4)	(1243.1)
Fusion	(500.1)	(510.0)
Non-nuclear energy R&D	1766.0	1807.1
Environmental R&D	219.3	245.1
Basic energy research	220.1	275.8
General science	431.1	474.1
Defense activities[1]	1074.3	1126.2
Other DOE R&D	14.6	18.5
TOTAL DOE R&D	$5530.9	$5699.9

Source: Agency budget justification.
[1] Excludes defense waste management and inertial confinement fusion, which are included in nuclear energy R&D.

are shown in Table 17; additional detail is provided in Table B–4 (Appendix B). The FY 1980 budget shows only a modest increase of 3.1 percent for total R&D in DOE, but it does include some significant program initiatives and realignments. The nuclear and non-nuclear energy R&D programs have already been discussed (see Table 12), so we will turn our attention here to the remaining programs shown in Table 17.

All of basic energy research and the nuclear and high energy physics programs in general science are included in the Office of Energy Research. The budget for the Office will increase by 15.9 percent in FY 1980 to a total of $707.8 million. The fundamental research activities in high energy and nuclear physics increase by 10.1 and 12.8 percent, respectively. Details of these budget proposals have been described in the "Disciplinary Highlights" on physics.

Basic energy research increases by 25.3 percent. Included are increases for all of the basic energy sciences and $5 million for a new program that will support thirteen coal research laboratories at universities. Since the basic energy sciences program is intended to expand the science and engineering knowledge base for new energy technologies, it is interesting to see how DOE has allocated the funds for this program according to technology. Table B–5 (Appendix B) shows that, as would be expected for a basic research program, almost half of the operating expenses cannot be assigned to any one technology. For the goal-directed activities, the largest increases are shown for solar technology and nuclear waste management.

Thus the DOE basic research program for FY 1980 is aimed at providing real growth for all scientific research, with important initiatives in

nuclear waste management, in advanced solar concepts, and in new opportunities for university participation in DOE research. A major influence in establishing these directions was the *Report of the OSTP Working Group on Basic Research in the Department of Energy*. Among the conclusions and recommendations of the group are

(i) A dearth of research is especially evident in the solar and fossil fuel programs.
(ii) Each Assistant Secretary should include a basic research category within his or her budget.
(iii) The overall basic research program should be of a size and scope sufficient to assure the health of disciplines important to the long-term development of energy technologies.
(iv) The budget for basic energy research in universities should be increased.

Trends in two other areas of Department of Energy R&D are noteworthy. The increase in environmental R&D includes a doubling of the budget for research on the effects of increasing carbon dioxide levels in the atmosphere (a total of $6.3 million in FY 1980) and an expansion of studies on the effects of low-level radiation on humans and animals. The proposals for R&D in defense activities include a small decrease in naval reactor development and a small increase in weapons R&D and testing.

D. R&D in the National Aeronautics and Space Administration

In his State of the Union message, President Carter devoted two paragraphs to the space program, mentioning maintenance of the shuttle development and production schedule, initiation of efforts on advanced satellite communications techniques, and increased remote sensing activities. This pretty well sums up the highlights of NASA's FY 1980 budget. As shown in Table B–6 (Appendix B), the total NASA budget increases by only $158.8 million (3.5 percent), assuming the FY 1979 supplemental request of $216 million for pay raises and the space shuttle is approved. Space enthusiasts will agree with the statement made by NASA administrator Robert A. Frosch at his budget press conference: "This is not one of my favorite budgets." Let us examine some of its major features.

First, over half of NASA's R&D operating funds goes for the shuttle program. Since the program is nearing completion, there is a decrease in funds for development and a concomitant increase in funds for space flight operations in preparation for launch activities. Funds for expendable launch vehicles are also declining as an increasing proportion of payload launches will be assumed by the shuttle. Assuming approval of the $185 million supplemental for the shuttle in FY 1979, NASA is

still trying to make its target date of 9 November 1979 for the first orbital test flight. The administration continues to structure its program around four orbiters, not five.

Second, while the budget for space science is scheduled to increase by 19.0 percent, no new space flight programs were approved in the FY 1980 budget. The higher level of funds is required to support projects already underway, such as the space telescope, the Galileo Jupiter Orbiter-Probe project, and the international solar polar mission.

Third, the future is not simply more of the present; some new activities are planned. Two major initiatives included in the FY 1980 budget are the multi-agency crop monitoring and production forecasting program and a re-entry by NASA into selected areas of communications satellite R&D. In addition, there is $8 million for solar power satellite research in the Department of Energy FY 1980 budget, a $3.5 million increase over the FY 1979 level. NASA will probably receive $3 to $4 million of these funds for research on the space-related technologies of such a system; for example, microwave power transmission and energy conversion.

Finally, a number of new projects considered by NASA lost out to the administration's "anti-inflation program with its necessarily stringent budgetary implications." These include a gamma ray observatory, a mission to map Venus by radar, a national oceanic satellite system, and a mission to fly past Halley's Comet on the way to a rendezvous with comet Tempel 2. These projects will be among the prime candidates for the "wedge" of new starts—about $200 million in FY 1981 and about $500 million in FY 1982—that the administration has provided for NASA in the forward projections in the FY 1980 budget.

E. R&D in the Department of Health, Education, and Welfare

Table 18 shows the amounts for R&D in each of the organizational units within HEW. We will comment here only on R&D in the National Institutes of Health and the Alcohol, Drug Abuse, and Mental Health Administration.

1. R&D in the National Institutes of Health

Undersecretary of HEW Hale Champion candidly and succinctly described the NIH budget at the HEW budget press briefing: "There will be less of it." How much less depends on the inflation rate, because, as shown in Table B–7 (Appendix B), the budget remains approximately level in current dollars. The increase from FY 1978 to FY 1980 is a respectable 14.7 percent—though still not allowing much, if any, real growth, given current inflation rates—and it is this increase plus the acceptance of the enormous congressional FY 1979 increase in NIH research funds that are the bases for the official rationalization of the level

Table 18. R&D in the Department of HEW (Budget Authority in millions).

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget	Percent change FY 1979 to 1980
Conduct of R&D				
Health				
National Institutes of Health	$2575.8	$2,956.4	$2958.2	+0.1%
Alcohol, Drug Abuse, and Mental Health Administration	180.2	217.7	259.4	+19.2%
Center for Disease Control	58.2	64.3	75.1	+16.8%
Food and Drug Administration	50.0	53.0	57.0	+7.5%
Office of Assistant Secretary for Health	33.9	34.2	29.5	−13.7%
Health Services Administration	15.4	15.6	11.1	−28.8%
Health Resources Administration	5.0	1.1	0.0	—
TOTAL Health	$2918.5	$3342.3	$3390.3	+1.4%
Education				
National Institute of Education	$ 90.1	$ 92.5	$ 94.3	+1.9%
Office of Education	43.5	37.0	41.3	+11.6%
Office of Assistant Secretary for Education	1.0	1.0	1.0	—
TOTAL Education	$ 134.6	$ 130.5	$ 136.6	+4.7%
Welfare				
Office of Human Development	$ 75.3	$ 86.1	$ 82.3	−4.4%
Health Care Financing Administration	28.7	18.8	35.0	+86.2%
Departmental Management	30.0	25.0	24.7	−1.2%
Social Security Administration	13.0	16.2	18.8	+16.0%
TOTAL Welfare	$ 147.0	$ 146.1	$ 160.8	+10.1%
Special foreign currency program	$ 11.4	$ 11.4	$ 6.5	−43.0%
TOTAL conduct of R&D	$3211.5	$3630.3	$3694.2	+1.8%
R&D facilities				
National Institutes of Health	$ 82.9	$ 85.8	$ 21.1	−75.4%
Food and Drug Administration	3.0	8.0	4.0	−50.0%
Alcohol, Drug Abuse, and Mental Health Administration	$ 0.4	$ 0.0	$ 0.0	—
TOTAL R&D facilities	$ 86.3	$ 93.8	$ 25.1	−73.2%
TOTAL R&D	$3297.8	$3724.1	$3719.3	−0.1%

Source: "OMB Data for Special Analysis L."

budget to the scientific community. To its credit, the administration, with OSTP playing an important role, has some significant achievements in its 2-year record on the NIH budget—Biomedical Research Support Grants have been reinstated as part of the President's budget proposals; the total NIH budget has been "tilted" toward basic research; and pressures within the administration to propose a rescission of the large congressional increase in the FY 1979 budget were overcome. To be sure, budget politics—as distinct from science policy—probably had some influence on the level funding proposed in the FY 1980 budget. The outcome of that game may be somewhat different this year, however, as there are some indications that even NIH may feel the effects of the budget restraint mood in Congress.

As it now stands, the FY 1980 budget would change the NIH funding patterns considerably. The situation is as follows: Most NIH research grants are awarded for 3 years. As a result of large NIH budget increases and the tilt toward more basic research, the many new grants awarded in FY 1978 and FY 1979 would place a relatively high mortgage on the level FY 1980 budget. The figures show that $1.1 billion would be needed for continuation in FY 1980, leaving $279.5 million for competing grants, down from $494.4 million in FY 1979. The award rate for competing grants would drop to 20 percent, compared to a 42 percent rate in FY 1978 and FY 1979. Mechanisms under consideration by NIH to alleviate these cutbacks include reprogramming money from contracts to grants, negotiating with current grantees to accept lower continuation awards, and using the new money in FY 1979 for one-time expenditures on special needs such as equipment and instrumentation that would strengthen basic research but would not mortgage future budgets. At the other end of Pennsylvania Avenue, the biomedical research community has launched a concerted effort to convince Congress of the need to increase funding by the amount necessary to maintain the current level of awards for competing grants.

A few special features of the NIH program are worth mentioning:

(i) Within the level budget, $11.4 million has been reprogrammed for increased emphasis on prevention research in the areas of smoking, toxicology, and international health (tropical disease).

(ii) An increase in the FY 1979 budget for population research in the Institute of Child Health and Human Development was not considered because the program had not been reauthorized by the time the Appropriations Bill was passed. To bring the program up to the level requested last year, the administration is requesting a $10.4 million supplemental for FY 1979 and a $5.6 million increase in FY 1980.

(iii) There is increased concern with the behavioral factors of disease in the Cancer; Child Health; and Heart, Lung, and Blood Institutes.

(iv) NIH is trying to make its research dollars go farther by extending the grant period to 5 years for the best investigators, shortening and clarifying the grant applications, and streamlining the reporting requirements.

2. *R&D in the Alcohol, Drug Abuse, and Mental Health Administration*

The ADAMHA research budget increases by 19.4 percent to $235.6 million in FY 1980, as shown in Table B–8 (Appendix B). This increase reflects the recommendations of the President's Commission on Mental Health and the basic philosophy that research should be the highest priority of the agency. Again this year, the ADAMHA budget justification states: "In terms of both economics and ultimate results, a strong research program is the best investment that can be made in promoting our primary goals." Almost all research programs in the three institutes will receive increases. Some areas of special emphasis are described below:

(i) In mental health, a major emphasis will be on the prevention of mental illness before it occurs. Areas of special concern are hospitalized children, postpartum parental competency, families going through divorce, death and pathological grief, major community disasters, high-risk suicides, and children with mentally disturbed parents.

(ii) Among the targeted areas in drug abuse research are characterization of the hazards of drug abuse, psychology of prevention and successful treatment, and historical patterns of substance abuse.

(iii) The increase in alcoholism research is part of HEW's FY 1980 Initiative on Alcoholism and Alcohol Abuse. Six areas are singled out for attention: women, youth, the fetal alcohol syndrome, occupational alcohol programs, HEW employee assistance programs, and domestic violence.

F. R&D in the National Science Foundation

To aficionados of federal science budgets, the President's FY 1980 budget is significant in that it includes the first billion-dollar ($1.006 billion) budget for the National Science Foundation. Table B–9 (Appendix B) shows that $935.7 million of the total is for R&D, an 8.8 percent increase over the current plan for FY 1979. R&D in the three basic science directorates would receive an overall increase of 10.1 percent; basic research, which is spread across all Foundation programs, would go from $741.0 million in FY 1979 to $828.3 million in FY 1980, an 11.8 percent increase. The increases for NSF are somewhat greater if the FY

1980 budget recommendations are compared with the budget authority actually approved for FY 1979, without the $16.8 million FY 1978 carryover which NSF has included in its FY 1979 figures. For example, the increase in total NSF R&D on this basis would be 11.0 percent instead of 8.8 percent.

There is significant variability in the increases allocated to the individual basic science programs. As pointed out in a special section of the NSF budget book, one must go beyond these numbers to program details in order to understand the budgetary mechanics and scientific judgments that were the basis for these decisions. Some of these have been discussed in the disciplinary "Budget Highlights." We will focus our attention here on a few areas of interest, most of which involve more than one research program in NSF.

(1) Going hand-in-hand with NSF's interest in maintaining a vital basic research enterprise is its continuing emphasis on research instrumentation and equipment. In order to illustrate the magnitude of the problem, NSF director Richard C. Atkinson pointed out that in western European countries the percentage of basic research funds spent on instrumentation is three times that in the United States. In FY 1980, NSF has requested $101.0 million for R&D facilities and equipment, of which $81.6 million is for research instrumentation and equipment—a 50 percent increase over FY 1979 and a 71 percent increase over the amount in FY 1977. A total of $4.8 million is requested for the regional instrumentation program to allow for three to five additional facilities, and $1.0 million is again earmarked for equipment costing $25,000 or less at 2- and 4-year colleges.

(2) In response to the concern that too much federally supported environmental R&D is targeted on specific problems and regulations, NSF was told to thread some exploratory environmental research throughout its budget. The increases in chemistry, atmospheric sciences, and environmental biology reflect this emphasis.

(3) In FY 1980, $8.0 million for microstructures research is included in the budgets for engineering, materials research, chemistry, and computer research. This is an increase of $3.8 million over FY 1979.

(4) A total of $7.0 million is included in the NSF budget for cooperative research between industry and universities—the $4.0 million shown in Table B–9 and another $3.0 million in the Applied Science and Research Applications Directorate. This program began late in FY 1978 with funds reprogrammed from an institutional support grant program added to NSF by Congress. Although NSF does not envision the industry/university program becoming a major budget item, it may take on added importance if the expected recommendation for enhanced cooperative research between industry and universities is forthcoming from the administration's Domestic Policy Review on Industrial Innovation.

(5) The budget for the Applied Science and Research Applications Directorate remains approximately level as NSF seems still to be defin-

ing its mission. Intergovernmental science and technology is the only area to receive a substantial increase. Small increases are provided for earthquake research, some programs on human nutrition (particularly the nutritional value of processed food), and technologies to aid the physically handicapped. The programs on community water management and chemical threats to man and the environment will be terminated.

G. R&D in the Environmental Protection Agency

Overall, the EPA budget emphasizes the same programs as last year's budget. For R&D, this means continued growth and increased visibility for research on health effects of pollution. EPA officials are touting the "public health initiative" as the focal point of EPA's FY 1980 budget and as an indication of the Agency's enhanced posture in the public health field.

The details of the increase proposed for R&D in the EPA budget are shown in Tables B–10 and B–11 (Appendix B). The research and development appropriation is scheduled to increase by 10.4 percent, the funds for the Office of Research and Development by 10.6 percent. Except for a small amount of funds in pesticides and program management and support, all the funds in the research and development appropriation are allocated to this office. The increase for the public health initiative totals $37.0 million and consists of increases in the areas of air quality ($15.0 million), toxic substances ($15.0 million), drinking water ($5.0 million), and nonionizing radiation ($2.0 million; the net increase for research on radiation effects is $0.9 million due to decreases in other programs). The initiative will focus on three R&D activities:

(i) The development of tests to permit rapid identification of the most toxic pollutants.

(ii) The refinement of techniques for conducting human population studies to confirm the results of laboratory tests.

(iii) The development of data on the movement of toxic pollutants through the environment.

The anticipatory program is the other area to receive a sizeable increase. This small basic research program almost doubles in size, going from $9.4 million in FY 1979 to $16.9 million in FY 1980. Although the National Academy of Sciences, the Office of Technology Assessment, and congressional committees have advocated increased long-term research to allow EPA to improve its ability to anticipate new environmental problems and to improve the scientific basis for regulatory actions, last year Congress cut the administration's request for the program on the grounds that improved management was necessary before the program should be allowed to grow substantially.

H. R&D in the Department of Agriculture

The units in USDA that support R&D are shown in Table 19. Additional details of the budgets for Agricultural and Cooperative Research are shown in Table B–12 (Appendix B). The Cooperative Research Service, the administrative home of both the competitive grants program and the formula grants to Agricultural Experiment Stations, was discussed in Chapter 4. Highlights of the R&D activities in the other units are the following:

(1) Within the approximately level budget for the Agricultural Research Service, there are several changes in program emphasis. Increases are provided for basic research in animal production, human nutrition, and human health and safety; research to improve energy efficiency in crop and animal production, including studies of solar heating and the production of energy from biomass; integrated pest management; and aerospace technology research as part of the interagency program on crop assessment and forecasting. We see here that the emphasis on basic research goes beyond the competitive grants program. Decreases are proposed for numerous individual projects on plant production and disease, and postharvest technology (processing, storage, distribution, and food safety).

(2) R&D in the Forest Service is proposed to decrease by 6.4 percent. The only program scheduled to increase is forest products utilization. Decreases are proposed for surface mine rehabilitation, recreation, forest engineering, and resource economics.

(3) Increases in R&D in the Economics, Statistics, and Cooperatives Service are for statistical studies, research, and policy analysis in such diverse fields as the role of small farms in agriculture and rural America; crop assessment and forecasting (part of the interagency program); water quality, conservation, and management; and food safety, quality, and nutrition.

I. R&D in the Department of Commerce

R&D in the Department of Commerce is scheduled to increase by 4.2 percent in FY 1980. As shown in Table 20, however, the two largest R&D agencies in the Department—NBS and NOAA—show increases of 11.2 and 9.6 percent, respectively.

Continuing the theme of the large increase proposed for NBS in last year's budget, two points come through loud and clear in the FY 1980 budget justification: (i) NBS has been increasingly burdened with requests "to meet the technical needs of a host of federal agencies," and (ii) the most important increase proposed for FY 1980 is for strengthening the Bureau's competence in basic scientific and technical research. Other major program increases are for research on the causes of the deterioration and failure of materials and for the development of meth-

Table 19. R&D in the Department of Agriculture (Budget Authority in millions).

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget	Percent change FY 1979 to 1980
Conduct of R&D				
Agricultural Research Service	$310.4	$344.4	$340.7	−1.1%
Cooperative State Research Service[1]	158.1	174.4	178.5	+2.2%
Forest Service	106.5	112.6	105.4	−6.4%
Economics, Statistics, and Cooperatives Service	32.7	35.9	39.8	+10.9%
TOTAL conduct of R&D	$607.7	$667.3	$664.2	−0.5%
R&D facilities				
Agricultural Research Service	$ 22.0	$ 48.9	$ 13.2	−73.0%
Forest Service	2.7	3.5	0.0	—
TOTAL R&D facilities	$ 24.7	$ 52.4	$ 13.2	−74.8%
TOTAL R&D	$632.4	$719.7	$677.4	−5.9%

SOURCE: "OMB Data for Special Analysis L."
[1] Includes Competitive Research Grants in FY 1978.

Table 20. R&D in the Department of Commerce (Budget Authority in millions).

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget	Percent change FY 1979 to 1980
Conduct of R&D				
National Oceanic and Atmospheric Administration	$172.1	$190.0	$208.2	+9.6%
National Bureau of Standards	54.1	66.9	74.4	+11.2%
Maritime Administration	19.6	18.7	17.3	−7.5%
Economic Development Administration	17.7	23.7	12.8	−46.0%
Other	13.2	15.4	15.1	−1.9%
TOTAL conduct of R&D	$276.7	$314.7	$327.8	+4.2%
R&D facilities				
Maritime Administration	$ 0.3	$ 0.3	$ 0.4	+33.3%
National Bureau of Standards	1.6	0.2	0.2	—
National Oceanic and Atmospheric Administration	2.3	0.0	0.0	—
TOTAL R&D facilities	$ 4.2	$ 0.5	$ 0.6	+20.0%
TOTAL R&D	$280.9	$315.2	$328.4	+4.2%

SOURCE: "OMB Data for Special Analysis L."

odology and data needed to recover resources from solid waste as mandated to NBS by the Resource Conservation and Recovery Act of 1976.

NOAA supports over half of the R&D in the Commerce Department. Major increases are proposed for research on ocean pollution and on the conservation, development, and management of commercial fisheries; there are also increases related to the National Climate Program and the interagency remote-sensing agricultural program described earlier. Looming large over the future of NOAA is the recently proposed reorganization plan that would transfer NOAA to a Department of Natural Resources along with the Department of the Interior and the U.S. Forest Service.

J. R&D in the Department of Transportation

Table 21 shows that R&D in DOT remains approximately level in FY 1980. Some of the trends and program emphases in the DOT units that support R&D are these:

(1) R&D in the Federal Aviation Administration declines by 2.1 percent. Support will continue for air traffic control systems, microwave landing systems, and radar beacons.

(2) The National Highway Traffic Safety Administration will continue its R&D efforts at about the FY 1979 level on driver and vehicle safety factors, automotive fuel economy, and the National Accident Sampling System.

(3) R&D in the Urban Mass Transportation Administration, which increases by 3.2 percent, is aimed at improving public transportation equipment and systems.

(4) Within the level funding proposed for R&D in the Federal Highway Administration, attention continues to be focused on improving highway, vehicle, driver, and pedestrian safety.

(5) Safety research is emphasized in the proposed 8.8 percent increase in Federal Railroad Administration R&D.

(6) Coast Guard R&D also increases by 8.8 percent. Activities include expanding the technology base and the development of equipment for search and rescue missions, navigation, commercial vessel safety, and marine environmental protection.

Of potential importance to future R&D activities in DOT are the Secretary of Transportation's continuing discussions with leaders in the automobile industry regarding a major long-term R&D program aimed at developing a new generation of automobiles.

K. R&D in the Department of the Interior

R&D in the Department of the Interior is scheduled to decline by

Table 21. R&D in the Department of Transportation (Budget Authority in millions).

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget	Percent change FY 1979 to 1980
Conduct of R&D				
Federal Aviation Administration	$111.5	$109.7	$107.4	−2.1%
National Highway Traffic Safety Administration	57.1	59.9	61.4	+2.5%
Urban Mass Transportation Administration	54.1	50.5	52.1	+3.2%
Federal Highway Administration	43.4	46.0	46.8	+1.7%
Federal Railroad Administration	41.8	40.8	44.4	+8.8%
Coast Guard	19.3	19.3	21.0	+8.8%
Office of the Secretary	25.0	16.4	11.5	−29.9%
Research and Special Programs Directorate[1]	0.9	11.5	10.7	−7.0%
TOTAL conduct of R&D	$353.1	$354.1	$355.3	+0.3%
R&D Facilities				
Federal Railroad Administration	$ 11.8	$ 11.2	$ 12.1	+8.0%
Federal Highway Administration	0.4	1.3	7.0	+438.4%
Federal Aviation Administration	6.9	0.3	5.9	+1,866.7%
Coast Guard	0.7	0.7	0.8	+14.3%
National Highway Traffic Safety Administration	0.2	0.2	0.2	—
TOTAL R&D facilities	$ 20.0	$ 13.7	$ 26.0	+89.8%
TOTAL R&D	$373.1	$367.8	$381.3	+3.7%

Source: "OMB Data for Special Analysis L" and *Budget Appendix.*
[1] For FY 1978 includes funds for activities in the Materials Transportation Bureau and the Office of the Secretary that have been transferred to the Directorate.

3.1 percent in FY 1980, as shown in Table 22. This decline results in large part from the decrease in metallurgy research in the Bureau of Mines. The mined-land demonstration program is again proposed to be eliminated; however, this program is not included in OMB's R&D data in Table 22. Last year Congress appropriated $16 million for the program after the administration had requested zero.

About half of the R&D in Interior is supported by the Geological Survey. Within the level funding proposed for FY 1980, increases are provided for wilderness mineral surveys, environmental aspects of coal development, water resource investigations, and application of space technology to resource and environmental analyses. The increase in water research in both the Geological Survey and the Office of Water Re-

Table 22. R&D in the Department of the Interior (Budget Authority in millions)

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget	Percent change FY 1979 to 1980
Conduct of R&D				
Geological Survey	$157.8	$172.9	$172.8	−0.1%
Bureau of Mines	117.3	124.5	107.1	−14.0%
Fish and Wildlife Service	30.3	36.0	36.1	+0.3%
Office of Water Research and Technology	24.7	27.7	30.1	+8.7%
Bureau of Reclamation	11.2	11.1	11.7	+5.4%
National Park Service	8.6	8.7	11.2	+28.7%
Other	5.5	9.0	8.7	−3.3%
TOTAL conduct of R&D	$355.4	$389.9	$377.7	−3.1%
R&D Facilities				
Office of Water Research and Technology	$ 0.6	$ 0.7	$ 0.7	—
Fish and Wildlife Service	7.5	3.3	0.0	—
Bureau of Mines	0.0	0.0	0.0	—
TOTAL R&D facilities	$ 8.1	$ 4.0	$ 0.7	−82.5%
TOTAL R&D	$363.5	$393.9	$378.4	−3.9%

Source: "OMB Data for Special Analysis L."

search and Technology is noteworthy in light of the mention made in the President's special message on science and technology of the great need in this area.

L. R&D in the Agency for International Development

For AID, the data on R&D available to us this year are much more comprehensive than those for previous budgets and evidently also more comprehensive than the statistics used in "Special Analysis L." Table 23 shows funds for R&D categorized by eight bureaus (in the past we have had data only for the Development Support Bureau) and eight functional accounts. The data must be viewed with caution, however. This is the first year AID has attempted to identify separately R&D in all its bureaus, and the definitional problems—a limitation of all R&D statistics, as we have already noted—are especially acute. Other factors also influence the validity of the AID data:

(1) The balance in AID programs between research and application of existing knowledge has always been a politically sensitive issue. In action on AID's FY 1979 budget, for example, Congress felt that the

balance had gone too far toward research in both the population and food and nutrition programs. Prudent avoidance of overexposure of needed but politically sensitive programs could mean that R&D is understated.

(2) Changing international political and economic environments can cause unplanned project starts and stops.

(3) R&D in the security supporting assistance account, almost one quarter of the total in FY 1980, is particularly difficult to identify. Funds in this account are paid to foreign governments on the basis of political exigencies—for example, the nearly $5 billion to be paid to Israel and Egypt as part of the Middle East Treaty agreement—and there is often no way to know how much goes to support R&D activities.

Even with these limitations, the data provide a useful window on the characteristics of R&D supported by AID. For the major components, for which summaries are shown in Table 23, we can make the following observations:

(1) Total R&D is expected to increase by 23.8 percent in FY 1980.

(2) Excluding security supporting assistance, most of which is in the Bureau for the Near East, about half of AID's R&D is funded by the

Table 23. R&D in the Agency for International Development (Budget Authority in millions).

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget
By Bureau			
Africa	$ 13.9	$ 14.3	$ 16.3
Asia	7.8	14.3	22.9
Latin America	7.8	16.2	19.9
Near East	11.9	37.5	48.1
Development Support	59.7	66.8	78.5
Program and Policy Coordination	3.4	6.1	5.6
Private and Development Cooperation	1.0	1.8	3.1
Intergovernmental and International Affairs	0.3	0.7	0.8
TOTAL	$105.8	$157.7	$195.2
By Functional Account			
Population Planning	$ 22.9	$ 30.3	$ 31.4
Agriculture, Rural Development, and Nutrition	53.4	61.3	76.3
Health	4.7	8.5	19.4
Education and Human Resources	3.5	7.3	7.6
Selected Development Assistance	7.3	10.1	7.4
Sahel Development Program	3.4	3.1	4.0
International Disaster Assistance	1.0	1.8	3.1
Security Supporting Assistance	9.6	35.2	45.9
TOTAL	$105.8	$157.7	$195.2

Source: Agency for International Development.

Bureau for Development Support. This is R&D centrally funded from Washington that is relevant to problems in several regions of the world. Included in the 17.5 percent increase in FY 1980 are large increases for two programs: (i) long-term tropical disease research (which increases from $4.4 million in FY 1979 to $8.6 million in FY 1980) and (ii) matching grants for U.S. land and sea grant universities to strengthen their capacity to assist less developed countries (which increase from $5 million in FY 1979 to $9 million in FY 1980). Other areas receiving support include biomedical, social, and policy research on fertility control and the effects of population growth; research on the education and skills essential to economic and social development; and research on new energy technologies and the application of earth satellite data to problems of development.

(3) R&D in the Bureau for Africa will increase by 14 percent. Of the $16.3 million total in FY 1980, $10.5 million is for agricultural and food research, 5 percent higher than in FY 1979. Health research and R&D in the Sahel Development Program receive the largest increases.

(4) In the Bureau for Asia, agricultural and population R&D receive the largest increases in FY 1980—45.4 and 10.7 percent, respectively. The AID budget documents state that inadequate food production and an increasing population are the two most important problems in Asia.

(5) About 83 percent of R&D in the Bureau for Latin America is for agricultural research. The increase of 56 percent in FY 1980 places special emphasis on research related to small farms in Central America.

A new actor may join the international development R&D scene this year. Initially proposed by President Carter in a speech in Venezuela in March 1978, and currently referred to by the administration as the Institute for Scientific and Technological Cooperation (ISTC), the new agency is intended "to strengthen the scientific and technical problem-solving capabilities of developing countries and focus increased U.S. scientific attention on development problems." The administration has sent a bill to Congress that would authorize creation of the new Institute; Senator Adlai Stevenson has submitted his own bill for a similar "Foundation for International Scientific and Technological Cooperation." While there are differences that will have to be resolved, the common objective of the proposals is to enhance the funding level and quality of science and technology for development and to insulate better the planning, management, and conduct of science and technology from the more political and operational development activities of AID. The administration is also proposing to reorganize international assistance activities into a new International Development Cooperation Administration, which would include AID, ISTC, the Overseas Private Investment Corporation, and possibly other units.

The FY 1980 budget includes $25 million in budget authority for ISTC, as well as estimates anticipating $40 million in FY 1981 and $100

million in FY 1984. In addition, R&D activities totaling $66.6 million are planned to be transferred from AID to ISTC in FY 1980. Funds for some 29 projects are involved; the largest amount is $29.6 million for the international agriculture research centers.

Chapter 6

R&D in Industry

We now go beyond the realm of federal R&D to consider R&D in industry. As the primary performer of federally funded R&D and as a source of about the same amount of R&D funds as the federal government, industry is clearly a major factor in R&D in the United States. A fairly comprehensive discussion of industry R&D was included in *AAAS–III*. This chapter is an update. We will present new data on industry R&D that have become available since *AAAS–III* and summarize some policy pronouncements and perceptions that differ somewhat from those described a year ago.

The analysis of R&D in industry presents problems of data availability, reliability, and interpretation that are even more severe than those for federal R&D. As we saw in *AAAS–III*, industry R&D is made up of thousands of companies acting independently, and there is no consolidated annual budget to facilitate analysis. Information on industry R&D is guarded closely and doled out carefully, if at all. Detailed statistics on industry R&D are generally sparse, out of date, and unverifiable. Only the most general data on individual companies are available. Nevertheless, the data that do exist indicate the major trends, raise some interesting questions, and provide a basis for discussion.

A. Statistical Overview

Overall estimates of industry R&D are now available in a more timely manner because of recent changes in the reporting procedures of the National Science Foundation. In the past, estimates by Battelle Columbus Laboratory, McGraw-Hill, and *Industrial Research/Development* magazine have used NSF data for prior years, together with their own survey results, to arrive at forecasts for industry R&D spending in the coming year. Last year, NSF began to make its own estimates for future years. In its *Highlights* and supporting tables for *National Patterns of R&D Re-*

Table 24. Estimated Total National Pattern of R&D, 1980, Current Dollars[1] (in billions).

Performers of R&D	Sources of Funds				
	Federal Government	Industry	Universities & Colleges	Other Nonprofit	All Sources
Federal government	$ 7.3	—	—	—	$ 7.3
Industry	14.3	$27.0	—	—	41.3
Universities and colleges	3.7	0.2	$1.2	$0.4	5.5
Federal R&D centers administered by universities	1.5	—	—	—	1.5
Other nonprofit	1.1	0.2	—	0.4	1.7
TOTAL by source	$27.9	$27.4	$1.2	$0.8	$57.3

Source: National Science Foundation, data for *National Patterns of R&D Resources, 1953–1980.*

[1] Amounts represent current operating costs, based on data by performers of R&D, and do not correspond to the figures for R&D in the FY 1980 budget. Capital expenditures are generally excluded.

sources, 1953–1980, available in early spring, NSF has stepped out ahead of the pack by providing estimates on industry R&D, with first-order breakdowns of the totals, for both 1979 and 1980. Our discussion is based primarily on these data.

Table 24 shows how industry is expected to fit in the national pattern of R&D in 1980. Industry will provide 48 percent of all R&D dollars. Most of this money ($27.0 billion) will support industry's own work, with the remainder ($0.4 billion) going to support R&D in universities and colleges and other nonprofit organizations. Industry is also estimated to perform $14.3 billion of R&D funded by the federal government, bringing its total to $41.3 billion, about 72 percent of the $57.3 billion national effort.

Moving on to Table 25, we can examine the overall trends in industry performance and support of R&D. In current dollars, total expenditures for R&D performed in industry in 1980 are expected to increase by 9.7 percent over 1979, which is now estimated to be 12.5 percent greater than the 1978 level (Table 25). Thus, if these estimates are correct, funding for industry R&D will be doing a little better than inflation, even if the inflation rate goes as high as 9 percent per year in 1979 and 1980 rather than the optimistic lower rates assumed in the FY 1980 budget and reflected in the constant-dollar portions of our tables.

The relative contributions by government and industry to total R&D performed by industry have changed drastically. When expenditures for large space and defense development projects peaked in the late sixties, industry R&D was supported about equally by the federal government and by industry itself. Since that time, the federal contribu-

tion has dropped substantially and in constant dollars has increased only slightly since 1972. Industry's own support of R&D, however, has shown a steady, real growth since about 1972. In 1979 and 1980, about 65 percent of R&D performed in industry will be supported by industry's own funds; the federal government will support the other 35 percent. As can be seen in Table 26, the overall totals for R&D funded by industry follow the same general trends as industry's support of R&D performed within industry, with estimated increases in current dollars in 1979 and 1980 of 11.8 percent and 10.7 percent, respectively.

The NSF statistics, then, indicate that funds for industry R&D are

Table 25. R&D Performed by Industry by Source of Funds (in billions).

Sources of funds	1967	1972	1978	1979	1980
Current dollars					
Federal government	$ 8.37	$ 8.02	$11.70	$13.33	$14.35
Industry	8.02	11.52	21.80	24.37	27.00
TOTAL	$16.39	$19.54	$33.50	$37.70	$41.35
Constant 1972 dollars					
Federal government	$11.53	$ 8.02	$ 7.63	$ 8.18	$ 8.14
Industry	11.04	11.52	14.21	14.96	15.31
TOTAL	$22.57	$19.54	$21.84	$23.15	$23.45

Source: National Science Foundation, data for *National Patterns of R&D Resources, 1953–1980*. Conversion to constant 1972 dollars by the authors using the annual calendar-year GNP implicit price deflators of the Department of Commerce, Bureau of Economic Analysis, and the corresponding projected deflators for 1979 and 1980 contained in the President's FY 1980 budget.

Table 26. R&D Funded by Industry, by Performers of R&D (in billions).

R&D performers	1967	1972	1978	1979	1980
Current dollars					
Industry	$ 8.02	$11.52	$21.80	$24.38	$27.00
Universities and colleges	.05	.08	.15	.16	.18
Other nonprofit	.07	.10	.13	.14	.15
TOTAL	$ 8.14	$11.70	$22.08	$24.68	$27.33
Constant 1972 dollars					
Industry	$11.04	$11.52	$14.21	$14.97	$15.31
Universities and colleges	.07	.08	.10	.10	.10
Other nonprofit	.10	.10	.08	.08	.09
TOTAL	$11.21	$11.70	$14.40	$15.15	$15.50

Source: National Science Foundation, data for *National Patterns of R&D Resources, 1953–1980*. Conversion to constant 1972 dollars by the authors using the annual calendar-year GNP implicit price deflators of the Department of Commerce, Bureau of Economic Analysis, and the corresponding projected deflators for 1979 and 1980 contained in the President's FY 1980 budget.

expected to increase at rates greater than inflation in both 1979 and 1980. How much faith can one have in these estimates? While the inherent limitations of the data base and the uncertainties of forecasting give fair cause for doubt, there are reasons to believe that the general trend of significant increases is real. First, additional data obtained by NSF in the past year have caused Foundation officials to give more weight in their estimates to industry forecasts of increased R&D activity and have led them to revise upward their estimates for both 1978 and 1979. This applies primarily to R&D funded by industry itself. Second, other forecasters are also projecting greater increases in industry support of R&D in 1979 than NSF estimated a year ago: Battelle Columbus Laboratory estimates a 14.6 percent increase over 1978; *Industrial Research/Development* magazine, 12.7 percent; and *Chemical and Engineering News* estimates a 10 percent increase for R&D in the largest U.S. basic chemical companies. The McGraw-Hill estimates for 1979 were not available when we went to press, but their estimates last year for industry performance of R&D were already higher than the NSF estimates.

B. What Is the Money Going For?

Now let us see what the available breakdowns of the NSF figures and other available data show about how the totals for industry R&D are expected to be spent.

Table 26 shows the breakdown by class of performer of R&D funded by industry. We have already noted the strong increasing trend in R&D funded by and performed in industry. The figures show a much weaker trend for industry support of R&D at colleges and universities: Current dollars rise from 1978 to 1980, but any real increase is wiped out by inflation. Looking ahead to Table 28, we see the picture is the same for industry-funded basic research at universities. Thus the NSF estimates evidently do not anticipate a real increase in 1979 or 1980 for industry support of academic research, in spite of the repeated statements by many top industry, university, and government leaders that this would be desirable.

Tables 27 and 28 give breakdowns by character of work of the totals for R&D performed and funded by industry, respectively. Applied research and development exhibit the same trends as the corresponding totals, which they dominate in a statistical sense: Substantial increases in current dollars in 1979 and 1980 seem to guarantee a small amount of real growth in spite of inflation. The trends in basic research deserve further attention; then we can go on to see what the available data show about the details by type of industry.

1. Basic Research

For basic research, we see that the totals funded and performed by

Table 27. Character of R&D Performed by Industry (in billions).

Industry-performed R&D	1967	1972	1978	1979	1980
Current dollars					
Basic research	$ 0.63	$ 0.59	$ 0.99	$ 1.12	$ 1.25
Applied research	2.92	3.51	6.34	7.20	8.00
Development	12.84	15.43	26.17	29.38	32.10
TOTAL	$16.39	$19.54	$33.50	$37.70	$41.35
Constant 1972 dollars					
Basic research	$ 0.87	$ 0.59	$ 0.65	$ 0.69	$ 0.71
Applied research	4.02	3.51	4.13	4.42	4.54
Development	17.68	15.43	17.06	18.04	18.20
TOTAL	$22.57	$19.54	$21.84	$23.15	$23.45

Source: National Science Foundation, data for *National Patterns of R&D Resources, 1953-1980*. Conversion to constant 1972 dollars by the authors using the annual calendar-year GNP implicit price deflators of the Department of Commerce, Bureau of Economic Analysis, and the corresponding projected deflators for 1979 and 1980 contained in the President's FY 1980 budget.

industry exhibit a common pattern. In constant-dollar terms there was a decline from the late sixties to the early seventies, but the 1978 totals are well above 1972 and substantial further increases are projected in 1979 and 1980—increases which would represent real growth even under pessimistic inflation assumptions. The picture of basic research in industry is brighter than it seemed a year ago. Reestimates have revised upward the total amounts for 1978 by about 10 percent, and the constant-dollar trend line is up rather than level.

Has industry changed its outlook and planning for basic research? Or do we now just have better statistics on what has been happening all along? In either case, will the increases actually materialize in the face of continuing inflation and probable recession? These questions are worth pondering and debating, but it is hard to see how there can be definitive answers in advance.

The available NSF statistics do offer another way of looking at industry's overall attitude toward basic research: One can look at the percent of total industry-funded R&D that goes to basic research and hypothesize that this is an indicator of the relative emphasis that industrial firms, on the average, are placing on long-term research as contrasted with near-term development. This approach was used in a recent study, *Support of Basic Research by Industry*, conducted by the Industrial Research Institute/Research Corporation for NSF. That study pointed out that from 1953 to 1975 the basic research ratio dropped from 6.0 percent to 3.7 percent for *in-house* industry-funded R&D. Updating the analysis with the revised data now available, we have found that the basic research ratio continued to dip slightly after 1975 but under the NSF esti-

mates for 1979 and 1980 would rise back to the 1975 figures. When *all* industry-funded R&D and basic research are considered, however, the downward trend in the basic research ratio is only slightly reversed in 1979 and 1980 and remains well below the 1975 figure. This seems to indicate that while the NSF estimators anticipate a small, barely detectable shift toward basic research in industry's allocations of its R&D dollars, their forecast of an increasing trend in industry funding of basic research is primarily a reflection of their expectation of increases in total industry-funded R&D.

Another approach and data source suggests that there may indeed be a significant shift in industry toward longer-term R&D. The McGraw-Hill industry R&D reports present data and forecasts on both industry R&D aimed at improvements in existing products and that which is aimed at new product development. The McGraw-Hill 1978 report presented data showing that, in 1977, 57 percent of total industry R&D expenditures (federal- and industry-funded combined) went toward the improvement of existing products; this is a decrease from the 59 percent projected for 1977 in the previous year's report. The share aimed at existing products was projected to drop further, to 48 percent, in 1978. If the McGraw-Hill figures accurately reflect the plans of industry, the "system" is actually moving in the direction of more emphasis on the long-term research called for by many leaders in government and industry. It will be interesting to see whether the 1979 report (not available at this writing) sustains this estimate for 1978 and projects a further decrease in 1979.

Table 28. Character of R&D Funded by Industry (in billions).

Industry-funded R&D	1967	1972	1978	1979	1980
Current dollars					
Basic research	$ 0.49	$ 0.56	$ 0.92	$ 1.03	$ 1.15
Universities only	(.03)	(0.5)	(.09)	(.09)	(.10)
Applied research	1.89	2.61	4.95	5.61	6.27
Development	5.76	8.52	16.21	18.04	19.91
TOTAL	$ 8.14	$11.70	$22.08	$24.68	$27.33
Constant 1972 dollars					
Basic research	$ 0.67	$ 0.56	$ 0.60	$ 0.63	$ 0.65
Universities only	(.04)	(.05)	(.06)	(.06)	(.06)
Applied research	2.60	2.61	3.23	3.44	3.56
Development	7.93	8.52	10.57	11.08	11.29
TOTAL	$11.21	$11.70	$14.40	$15.15	$15.50

Source: National Science Foundation, data for *National Patterns of R&D Resources, 1953–1980*. Conversion to constant 1972 dollars by the authors using the annual calendar-year GNP implicit price deflators of the Department of Commerce, Bureau of Economic Analysis, and the corresponding projected deflators for 1979 and 1980 contained in the President's FY 1980 budget.

2. *Detail by Industry*

The most detailed comprehensive data on R&D in industry are in the statistical report, *Research and Development in Industry*, prepared annually by NSF and the Bureau of the Census. These reports, based on a highly professional job of data collection and analysis, provide the best and in some areas the only detailed data available, although they are necessarily behind the times because of the time required for collection, analysis, and refinement of the statistics. In addition, the validity of the data has been somewhat diminished in recent years by a declining response rate to the NSF-Census surveys. If the data are to be of value to government and industry policy-makers, stronger efforts are needed to convince companies and their accountants of the need to respond fully and accurately to the NSF-Census survey questionnaires.

The most recent detailed NSF data on industry R&D are for 1976 and 1977. Tables C–1 to C–3 (Appendix C) show the NSF breakdowns of total federal- and industry-funded R&D by major industry group, of applied research and development by product field, and of basic research by field of science.

The only comprehensive public source of R&D statistics on individual companies is the so-called 10–K filings most public corporations are required to make annually with the Securities and Exchange Commission. The financial data on R&D consists only of a single annual total figure for R&D expenses for each company, exclusive of expenses for R&D performed under contract with the federal government or with other outside sources of funds.

For the last 3 years, *Business Week* has performed the useful service of compiling the 10–K R&D data by company. Table C–4 (Appendix C) summarizes the 1977 data and changes from 1976 for 624 companies, according to the categories used in *Business Week*. The totals of the *Business Week* data are about 90 percent of the corresponding NSF figures for 1976 and 1977. That there are substantial differences in the amounts reported to NSF and the Census Bureau and to the SEC is clear from the fact that the *Business Week* totals show a 16.4 percent increase from 1976 to 1977, whereas the NSF-Census data show a corresponding increase of only 11.3 percent. The 10–K data, in total and by industry group, provide a significant indicator of industry decisions, confirming that substantial increases in industry R&D funding did indeed take place in the years reported and giving another insight into the trends in various types of industries.

C. The Policy Outlook

Policy positions and attitudes on R&D in industry, in government and industry circles, do not appear to have changed significantly over the last year. Some positions have been reaffirmed, with new shadings,

active discussion has continued, and expectations for new light and guidance on the federal outlook are focused on the results of the presidentially mandated Domestic Policy Review on Industrial Innovation scheduled to be available in May 1979.

The general policy outlook of the federal government on R&D was reaffirmed in the *FY 1980 Budget*, the President's State of the Union message, and his special message on science and technology. The main points are these:

(1) Although the federal government accepts the primary responsibility for assuring support of basic research in the nation, industry should also seek to maintain a high level of investment.

(2) In civilian areas such as energy, the private sector should be expected to finance R&D on projects where technical risks are low and development times short.

(3) The government role in enhancing the level and efficacy of industrial R&D lies in doing what it can to improve the investment climate, economic growth, trade prospects, and policies relating to patents, antitrust, procurement, and environmental regulation. Direct government support of industry R&D is not needed.

(4) "Many practical recommendations" are expected from the Domestic Policy Review of the factors affecting industrial innovation.

In the presidential documents, the topics of R&D, innovation, productivity, and the economy are loosely interwoven to give a sense that R&D has a critical role in producing innovation, increasing productivity, and improving the economy. There is, however, noticeably less emphasis this year than last on a direct tie between basic research and economic benefits; the justification for increased federal support of basic research has shifted slightly, giving more emphasis to its contributions for solving important national problems, while still reaffirming in general terms its necessary and beneficial contributions to increased productivity. Two official reports issued during the past year contain suggestions of these new directions in government thinking in the areas of R&D and innovation.

In the 1979 *Economic Report of the President*, the Council of Economic Advisers discuss briefly the relationship between R&D and productivity. In searching, admittedly not very successfully, for the reasons for the apparent decline in the rate of growth of U.S. productivity, they discount the view that a decline in overall R&D expenditures has been a major factor. Their reasoning is (i) the reduction in total R&D spending over the past decade has resulted mainly from cutbacks in defense and space research, which they regard as having a less direct effect on productivity than basic research or industry R&D; and (ii) the level of industry R&D has remained at about 1 percent of GNP since the mid-1960s. Their surmise, therefore, is that a shift within industry R&D spending away from basic research and new product development may have been a factor in the productivity slowdown. It is interesting that they appear to accept the view that changes in levels of basic research funding can

have relatively short-term effects on productivity; other observers have viewed these effects as requiring a much longer time to manifest themselves.

The first annual *Report to the Congress on Science and Technology*, prepared by NSF in August 1978, contains some material that puts a new slant on another of the conventional wisdoms of science and technology policy. While deferring to the results of the industrial innovation study, the report seems to call into question one of the basic assumptions on which the need for that study was based. It presents data indicating that the R&D intensity (ratio of R&D expenditures to value added) of U.S. manufacturing industries compares favorably with that of all industrial nations and concludes that the available data indicate little or no erosion in U.S. technological capabilities. It states that, while the United States can no longer expect to be the leader in all technical fields, we continue to gain strength in the commercial exploitation of technology. "Neither the available economic nor technical indicators provide hard evidence of an eroding U.S. technical position which can be tied to negative economic consequences." This is a somewhat startling conclusion in an official report from an administration that has expressed concerns and based policy on the view that a serious problem exists. It will be interesting to see the Domestic Policy Review's conclusions on this point.

Thus, we come back to the Domestic Policy Review on Industrial Innovation. Announced about a year ago and shifted into high gear early last fall, the study, under the direction of the Department of Commerce, is intended to arrive at some answers to the President's request for policy initiatives that would help U.S. industry improve its record on innovation. To develop the recommendations the study has used a multifaceted system of government agency task forces and external advisory committees concerned with seven topics: procurement; direct support for R&D; environment, health, and safety regulations; regulation or industry structure and competition; economic and trade policy; patents; and information. The original intention was to have recommendations to the President by the beginning of April 1979. At this writing, however, the date has been moved ahead to May as the Department of Commerce and the Executive Office of the President wrestle with many more options than they had anticipated and attempt to analyze the cost and political implications of their recommendations.

Will the study make a difference? Present opinions seem widely divided. Some observers feel the effort has been worthwhile, that the federal agencies and industry have examined the problems on common ground, and that most of the proposed recommendations are reasonable, specific, and useful. Others disagree: criticism ranges from questioning the severity of the innovation problem on which the study was based to a feeling that the territory has been well-traveled already. In the words of a participant in previous exercises of this type, "What is lacking is an *evaluation* of the well-known policy options and some *action* on the selected ones." Action, however—in this case as well as with other often-

studied topics—seems likely to be determined as much by the particular confluence of personalities and political, social, and economic events as by the substantive merits of the case. For example, studies of the idea for an institute for scientific and technological cooperation, not formally recommended until 1979, began in the early 1960s. And even if the timing is now right in this instance, it will be several years after proposals are put forward by the President and acted on by Congress before significant effects on the industrial innovation process can be expected.

The administration's constant emphasis on the central importance of this policy review may have built up unreasonably high expectations in industrial, scientific and technical, and public policy communities. The official in charge of the review, Assistant Secretary of Commerce Jordan J. Baruch, has from the start tried to stress the complexity of the problem, the wide scope of the review, and his own minimal expectations. Nevertheless, whatever emerges is bound to be a new baseline for the next rounds of discussion of innovation and policies on industry R&D.

While the administration looks to its Domestic Policy Review for guidance and for ways to improve industrial innovation, other groups in and out of government also are studying the problem. In the Congress, both the Office of Technology Assessment and the Joint Economic Committee have efforts underway; several private centers are also studying ways to improve productivity. There seems to be wide agreement that a problem exists; it will be interesting to see how much concurrence there is on solutions.

Chapter 7

International Aspects of R&D

In this chapter we shall attempt to lay out a framework for consideration of the significant issues of current concern related to international aspects of R&D. This venture is a further broadening of the scope of this series of AAAS reports—beyond R&D in the federal budget and beyond R&D in industry and the economy. For one thing, we will look briefly at R&D in countries other than the United States. For another, we will find as we look at the international dimensions of U.S. R&D activities that the issues of principal interest tend to be those concerned with broader questions relating to science and technology (S&T) rather than to R&D as such.

"International R&D" is not easy to define. There are many quite different international aspects of R&D, each of interest and importance in its own right, each with its own constituencies, and each having significant issues of public policy associated with it. We shall make a brief survey of the terrain in terms of fourteen categories which seem to cover the principal areas of interest. The categories overlap and have many interrelations, but taken together they may provide a framework for considering the whole range of topics of interest.

For each category, we will outline briefly the international aspects of R&D with which we are concerned and indicate the kinds of issues involved. We will also consider whether and to what extent it is possible to identify the R&D of interest in budgetary or other statistics—what some have called the "international R&D accounting problem." The answers we will find are not very satisfying, but consideration of the problems may provide some food for thought on what kinds of data it would be useful and reasonable to seek to have collected.

In the final section, we will leap from the generalities of a quick survey to a listing, with minimal discussion, of some of the key issues relating to international aspects of R&D that are of current concern. We shall not presume to give conclusions; our aim is to identify for dis-

cussion at the AAAS colloquium and elsewhere some of the most important operative questions of public policy on international aspects of R&D that need to be dealt with in the months ahead.

A. The Principal International Concerns

Three international aspects of R&D stand out in terms of policy significance: the roles of R&D in national security, in international economic interests, and in assistance to developing countries.

1. R&D and National Security

Department of Defense R&D is, of course, the major component of federal R&D directed at national security. It is "international" in the obvious sense that its main focus is the development of weapons and other military systems for use in deterring and, if necessary, fighting international adversaries. Its content and priorities are based in part on assessments of the scientific and technical capabilities of other nations and the directions and quality of their R&D. It involves scientific and technical collaboration and sometimes joint projects with our allies.

National security R&D which has international implications also includes several programs in departments other than Defense. Department of Energy R&D on nuclear weapons and nuclear propulsion, and NASA space shuttle and aeronautical R&D directly support military requirements. National security considerations are a factor in some international assistance programs; Table 23 in Chapter 5 shows that about 23 percent of AID's R&D is now considered "security supporting assistance." Arms control planning and negotiations depend on many kinds of R&D, including strategic research, assessment of verification methods, and study of the impact of new technologies and "technology creep" on actual or contemplated arms control agreements. A broader concept of national security could include R&D on alternate energy sources to reduce dependence on foreign oil, a goal which has national security as well as economic motivations. The case can even be made that our national security, in the broadest sense, depends on a healthy economy—with that logic all R&D which provides economic benefits could be said to support national security and therefore to have international implications.

The category of national security R&D with international implications would include, almost by definition, virtually all matters related to direction, content, and pace of military R&D. Specialists in various fields might regard some issues—like development of strategic weapons—as having greater "international" significance than others, but it seems quite arbitrary to try to carve out an "international" subset of military R&D budgets or issues and exclude the international significance of the

remainder. From the arms control standpoint, significant issues include the impacts of R&D itself, especially strategic systems testing, on the terms and stability of existing or hoped-for agreements. Another set of difficult issues relates to export control of R&D results and new technologies of national security significance. These issues include how to balance the protection of technological advantages for national security against the conflicting goals of openness in science, expansion of trade, and furtherance of specific foreign policy objectives.

In an attempt to quantify "international R&D" from the national security perspective in terms of budget authority in the FY 1980 budget, one could take total DOD R&D ($14,228 million), DOE defense-related R&D ($1,478 million), NASA shuttle development and production- and defense-related aeronautical R&D ($2,050 million), AID "security supporting assistance" ($46 million), and Arms Control and Disarmament Agency (ACDA) R&D ($4 million), for a combined total of $17.8 billion. Alternate energy R&D, if included, would add about another $3.5 billion, but the amount for R&D with economic benefits is indeterminate.

2. *R&D and U.S. International Economic Interests*

R&D is related to U.S. international economic interests through its contributions to advancing science and technology which may lead to innovations in U.S. industry which, in turn, may enhance the competitive position of the United States in world trade. The long and loose linkage involved was discussed in some detail in *AAAS–III*.

The R&D and S&T issues under this head go back to some broader fundamental questions. Has U.S. innovativeness in fact declined in either an absolute or a relative sense? Is its decline (or failure to increase as much as would be desired) attributable to missed opportunities or barriers to innovation in the United States? Or is it a to-be-expected consequence of vigorous competition by other nations as they achieve their proper positions on the world scene? What policy changes in government and industry are needed to advance U.S. international economic interests? Should there be closer economic cooperation with other countries? Selective import controls? From the standpoint of U.S. economic interests, how should our policies be different for relations with other developed countries; developing countries; newly industrializing countries; OPEC countries; and the USSR, China, and other communist countries?

The S&T and R&D aspects of these issues center first on the extent to which S&T and R&D are a significant part of economic problems or offer opportunities for dealing with them. Perhaps the most important specific question is whether S&T or R&D can find a way to reduce materially our dependence on imported oil. More generally, the operative question as far as R&D is concerned is whether changes in U.S. R&D—funding levels, content, or policies—are necessary or desirable to help

improve the international economic position of the United States. As discussed in the previous chapter, the hope is that the report of the Domestic Policy Review on Industrial Innovation will shed important light on these and the entire complex of related issues.

There does not seem to be any way of distinguishing, statistically or otherwise, the U.S. R&D activities that have international economic significance. The McGraw-Hill estimates, discussed in Chapter 6, give an estimate of the portion of industry R&D expected to be devoted to new products, but even if this is accepted as a measure of industry R&D directed to innovation, there does not seem to be any basis for estimating how much is intended or likely to have an impact on U.S. international economic interests.

3. R&D and Assistance to Developing Countries

Technical advice and assistance have been a central theme in U.S. foreign aid programs from the beginning. To a large extent this has involved the application of existing knowledge and technologies, not R&D in the ordinary sense. Special programs of R&D, however, have been directed at problems of special importance to developing countries, and some R&D conducted primarily for other purposes has found useful applications in foreign assistance programs.

There is a wide and confusing range of current issues relating to science and technology (S&T) aspects of assistance to developing countries. Many of these have been receiving exhaustive treatment in the past few years in the preparations, here and abroad, for the United Nations Conference on Science and Technology for Development (UNCSTD) to be held in Vienna, Austria, in August 1979. Agenda items for the conference cover the choice and transfer of S&T for development, elimination of obstacles to its utilization, methods of integrating it in economic and social development, new S&T for overcoming obstacles to development, institutional arrangements for cooperation in S&T, infrastructure requirements for S&T in the developing countries, R&D in industrialized countries on problems of developing countries, strengthening of cooperation among developing countries and among all countries, and utilization of existing U.N. and other international organizations. The positions to be taken by the United States at UNCSTD and the U.S. responses to what happens at UNCSTD are major current policy concerns.

Besides UNCSTD-related issues, there are S&T issues related to many of the basic questions of U.S. policy, organization, and levels of support in the foreign assistance field. These include the conditions and mechanisms for technology transfer to the less developed and to newly industrialized countries; the relative emphases to be given to high, medium, low, or "appropriate" technology; the balancing of economic, political, national security, energy, and human considerations; the relative

reliance on bilateral, multilateral, regional, or international agency approaches; the roles and interactions of U.S. government and private sector activities; and the reorganization of the federal establishment dealing with the S&T aspects of assistance to developing countries.

On the reorganization front, the main issue of current interest from the S&T standpoint is the congressional response to the administration's proposal for establishing the Institute for Scientific and Technological Cooperation. As discussed in our earlier section on AID's R&D, the ISTC is intended to provide a new focus within the overall U.S. foreign assistance establishment to strengthen the S&T problem-solving capacities of developing countries and focus increased U.S. scientific attention on development problems.

From the narrower standpoint of R&D, the basic issue is what R&D is needed and should be done to further the aims of U.S. assistance to developing countries. One systematic attempt to identify substantive areas of R&D that deserve special emphasis by the United States was the April 1978 report of the National Research Council, *U.S. Science and Technology for Development*. Other sets of recommendations are in the planning office papers for ISTC and in the budget justification materials submitted by AID to Congress.

As for budget statistics on this aspect of international R&D, we can start with the AID budget, which contains almost all of federal R&D directed at problems of developing countries. As summarized in Table 23, these amounts are estimated to total $195 million for FY 1980. Most of the $25 million for the proposed new Institute for Scientific and Technological Cooperation would presumably be classified as R&D. Beyond this, one may identify relatively small amounts in HEW, NSF, Department of Agriculture, and possibly other agencies, for R&D directed primarily at problems of developing countries. We estimate that the total of these amounts would be in the neighborhood of $250 million for FY 1980.

It should be possible for OMB, NSF, or AID to compile, if they wished, a more complete and accurate set of budget statistics on R&D *directed* at needs of developing countries, although this does not seem to have been done up to now. If, however, one asks how much funding goes for R&D that could *benefit* developing countries, or is *related* to their needs, the answer becomes indeterminate; absent a definitive catalogue of the needs of developing countries and the clairvoyance required to anticipate the potential spin-off applications of R&D, it does not seem reasonable to expect such estimates. The question itself is flawed—the significant point would seem to be the totality of science and technology relevant to problems of developing countries, not how much is added through R&D in any particular year. Also, the *cost* of conducting R&D that has spin-off benefits for foreign assistance appears to be irrelevant; what counts is its *value* and availability for meeting the needs of the developing countries.

B. The Many Other Facets

The interest in and priority deserved by the "big 3" international aspects of R&D—security, economics, and assistance—should not obscure the importance of the many other international facets of R&D. We will mention about a dozen of these, grouped for convenience under three major heads. There is much overlapping, but each facet is different and has its own problems and issues. In one or two cases we can find some pertinent budgetary statistics.

1. Foreign Policy and R&D

There are significant interactions of U.S. foreign policy with S&T and R&D in areas other than the "big 3" discussed above. Five additional types can be distinguished:

a. Foreign Policy Implications of R&D and S&T. Many U.S. policies and activities in S&T and R&D have important foreign policy implications. The Department of State's first *Report to Congress on Science, Technology, and Foreign Policy* cites as examples the areas of nuclear and nonnuclear energy, oceans and the atmosphere, health and nutrition, population, agriculture and food technology, and space technology. The issues are different in each case; the problem is usually to ensure that a technically competent U.S. agency with good outside advice is on top of the technical aspects and that the U.S. policy-makers and negotiators understand them. It may be possible to find statistics on R&D related to a particular technical problem, but overall statistics on this category are out of the question.

b. S&T Aspects of General International Problems. There are also many political and administrative matters in the conduct of foreign affairs which are not primarily S&T, national security, economic, or foreign assistance concerns but which nevertheless have important S&T aspects and may even require R&D. Examples are the "Law of the Sea" negotiations, drug traffic control, and the setting of international standards in fields like aviation, health, and environmental pollution. Again the issues are specific to each situation and general statistical data on the R&D involved are probably neither obtainable nor meaningful.

c. R&D Requiring Foreign Assistance. Facilities and assistance required abroad by U.S. R&D activities frequently involve diplomatic negotiations with other countries. Examples arise in meeting needs for foreign stations for space tracking or geophysical data collection and in making special arrangements to secure unique foreign equipment, specially qualified expertise, or scarce materials. A recurring problem is the degree to which such negotiations become involved in broader political negotiations or problems with the same countries. Again R&D statistics can be expected only on specific activities.

d. R&D and S&T as a Diplomatic Tool. Bilateral or multilateral

agreements on R&D and S&T cooperation are often used as a step toward other diplomatic objectives, and U.S. actions under such agreements may be modulated to support broader foreign policy considerations. Over 200 such agreements are currently in force; while some have been motivated primarily by U.S. scientific or technical interests, many have been the result of political interests or initiatives of the United States or the other countries. Besides the specific issues in each case, some general problems recur in this area. There is often a lack of adequate advance preparation before visible top level commitments are made, so the ensuing agreements may be unworkable or create unrealistic expectations on either or both sides. There is often insufficient follow-through after agreements are entered into, especially in ensuring adequate financial support for carrying out the commitments made. Then there is the question of the mutuality or one-sidedness of benefits and the evaluation of performance on both sides. Apparently there has been no central scorekeeping on U.S. budgetary support for international scientific and technical agreements.

e. R&D, S&T, and International Organizations. Finally under this head, there are the foreign policy aspects of U.S. participation in international S&T organizations—the various U.N. intergovernmental organizations in which the U.S. government participates and the international scientific and professional organizations in which U.S. participation is through individual U.S. scientists, professional societies, or institutions like the National Academy of Sciences. Typical issues raised by U.S. activities in such forums include the problems of establishing official U.S. positions when the government is directly involved and of dealing with the diplomatic implications of stands taken by private U.S. individuals and organizations on international issues such as human rights. It might be possible to make a tally of the direct budgetary costs of federal R&D or S&T activities that directly support U.S. participation in international organizations; apparently this has not yet been done.

2. *R&D in International Contexts*

Under this head we will note briefly four international aspects of R&D itself.

a. R&D on Global Problems. For many R&D problems the subject matter is inherently international. Examples are research on world-wide phenomena, such as weather, climate, and population growth, and the development of systems for world-wide applicability, such as remote sensing of resources from space. Budget statistics are feasible in some of these areas; figures on climate research, for example, were presented in Table 15.

b. International Scientific Cooperation. In the United States, international scientific cooperation is widely regarded as a goal in itself—in consonance with, apart from, or sometimes even in spite of foreign policy considerations. Obvious examples range from informal cooperation

among professional colleagues in different countries to formalized scientific personnel exchanges and joint projects under a variety of arrangements. Typical issues relate to mechanisms, the respective roles of government and private organizations, and the control of security-sensitive and proprietary data. Budget figures might perhaps be assembled for major federal cooperative projects and for offices specifically engaged in their management, but international cooperation is so often a feature of R&D undertaken primarily to serve other interests of the United States that a complete tabulation is not likely to be possible.

c. International Competition in R&D. Foreign competition often serves as a spur to excellence or as a justification for U.S. R&D programs or budgets. Major U.S. initiatives in R&D have been stimulated by or "sold" on the basis of the desire to keep U.S. S&T equal to or ahead of that of other countries. Obvious examples are space exploration and the building of ever more powerful particle accelerators for high energy physics research. Issues under this head range from arguments on the relevance of competition in each case to basic philosophical questions concerning U.S. goals in science and technology. It is interesting to speculate on the net cost to the United States of competitive R&D, but any attempt at measurement would have to face the intangibles of the costs of hypothetical alternatives and the values of scientific leadership.

d. Use of Foreign Capabilities. The final entry under this head is the use of foreign R&D capabilities by the United States. This is often one of the important motivations in cooperative or joint international R&D activities. In its most direct form, federal agencies or U.S. industry actually finance R&D in foreign countries. This is one of the few areas for which some budgetary statistics are available, for what they may be worth. Tables D–1 and D–2 in Appendix D summarize the most recent NSF "actual" data on federal R&D performed in foreign countries and industry R&D performed abroad by foreign affiliates, respectively.

For foreign-performed federal R&D, the "Detailed Statistical Tables" for NSF's *Federal Funds XXVII* show a very large jump in the total from the "actual" FY 1977 figure of $88.2 million to about $124 million estimated for both FY 1978 and FY 1979. It is not known how much of this increase is actually being realized or how much may reflect changes in reporting. For company-funded R&D performed abroad by foreign affiliates of U.S. industry, the latest figures place the 1976 total at $1.3 billion, the bulk of which is about equally divided between the chemical, machinery, electrical, and "other" manufacturing categories; the trend data indicate current dollar increases of 13.0 percent in 1975 and 10.8 per cent in 1976, respectively.

3. Two More Facets

Under this heading, we list two important areas, one relating to how the U.S. deals with international aspects of S&T and R&D, and the other relating to R&D in foreign countries.

a. U.S. Organization for International Aspects of S&T. Title V of the Foreign Relations Authorization Act of 7 October 1978 is a recent landmark in a long and difficult search for effective organizational arrangements for dealing with international S&T matters in the Executive branch. It states the importance that S&T and related matters should be given in the development and execution of U.S. foreign policy and (i) restates explicitly the general responsibilities of the President and the Secretary of State for coordination and oversight in this area, without treading too hard on the toes of other departments and agencies with international interests; (ii) recognizes State's need for funds and authority to support studies and analyses, obtain advice, and train civil and foreign service personnel in matters related to the interactions of S&T and foreign policy; and (iii) requires comprehensive reports to Congress to help ensure that the Act is carried out.

The provisions concerning studies and analysis, advice, and personnel training in S&T matters are especially noteworthy. They give specific legislative recognition to fundamental needs of the Department of State that have long been perceived by many observers but which have previously not received strong backing and support within the Department and in Congress. They also give statutory status to the establishment of mutually supportive links between the Department and the sectors of the academic community concerned with the interactions of S&T and foreign affairs. If OMB and Congress come through with the hard cash needed (Congress indicated that $4 million should be available within the FY 1979 appropriations), then State may emerge as a significant new funding source for academic research and training in international aspects of S&T.

The Bureau of Oceans and International Environmental and Scientific Affairs (OES) under Assistant Secretary of State Thomas R. Pickering is gearing itself up to administer the Act and has succeeded in meeting the tight statutory deadline for the submission of the first report to Congress. The policy areas to be dealt with cover almost the entire spectrum we have been discussing. There are formidable problems in asserting a stronger role for OES in long-established bureaucratic contexts—in relations between State and the agencies with international programs and interests, and in the policy decision process within the Department itself.

One interesting question is whether the enactment of Title V will mean that the Department of State will play an effective—or at least consultative—role in the budget process on matters affecting international aspects of S&T and R&D. In the general absence of mechanisms to integrate this varied and far-flung field, it might be useful if OES could be accepted into the "system" as having a role in international S&T matters similar to that now carved out by OSTP on budget matters relating to R&D and S&T in general.

What can and will be accomplished under Title V remains to be seen, but all who have felt that over the years the Department of State

has not been effectively organized and staffed to give international aspects of S&T the attention they deserve should welcome the effort and hope for the best.

b. Foreign R&D. A final and obvious aspect of "international R&D" is the study of R&D in foreign countries—organization, policies, budgets—as an interest in its own right and to see what the United States can learn from the experience of others. Statistical or substantive analysis of R&D trends and policies in other countries is beyond the scope of our report and our capabilities this year. The principal effort at assembling and analyzing statistical data on an international basis appears to be that mounted by the Organization for Economic Cooperation and Development (OECD), but there are obviously great difficulties in obtaining up-to-date data from so many countries and adjusting for differing national R&D systems, price levels, and so forth. The most current available data on total national R&D funding by the major industrialized nations are those assembled by NSF for *Science Indicators 1978*.

In Table D–3 in Appendix D, we have converted from national currencies to U.S. dollars the NSF-assembled data for gross national expenditures for R&D (GERD) of the principal industrial countries, using the average exchange rates for the years for which R&D data are available. The result shows that from 1972 to 1975 all of the other countries appear to have increased their total R&D expenditures at rates greater than that of the United States. Table D–3 also shows estimates of the real changes in total R&D funding in each of these countries, as measured by the difference each year between the percent increase in total GERD in current-year national currencies and the percent increase in consumer prices. This analysis shows very large real growth in GERD from 1967 to 1972 for Japan and West Germany, and substantial real growth for Canada and France, whereas there was a real decline for the United States. For 1972 to 1975, all countries except France and the United States show continuing real growth. For the post-1975 years, the U.S. trend is reversed, and real growth is continuing—but with fits and starts—in the other countries for which data are available.

C. Major International Issues

Now let us conclude by listing a selection of what appear to be the top ten issues of those mentioned or implied in our rundown of international aspects of S&T and R&D.

1. The Technological Arms Race

All indications point to the likelihood that the technological arms race will continue indefinitely, regardless of SALT or other arms control agreements, or de facto policies of restraint that may evolve. Does this mean that the United States should plan on continuing real increases in

military R&D over the next decade? Granting the need for continued advances in military technology, is there any underlying reason why there must also be continuing increases in the *rate* of technological advance, as reflected in an increasing annual total budget for military R&D? If continuing increases are necessary, what size defense R&D establishment are we headed for? What are the implications for industry and other performers of R&D?

2. *Expectations in International Economic Competition*

S&T and other policies related to U.S. international economic competitiveness depend crucially on underlying assumptions on the position the United States should and can reasonably expect to hold in relation to the other nations of the world. What should be our goals? What are realistic U.S. expectations in competing with other developed countries? With newly industrializing countries? With currently less developed countries as they develop? With the communist countries? What are the policy implications of a long-term "win some—lose some" status for the United States?

3. *International Competitiveness*

Another fundamental issue is the relationship between advances in S&T through R&D and the international competitive position of U.S. industry. Are current R&D and S&T policies in fact a significant part of the problem? Are changes in R&D policies a significant part of potential solutions? Is more government intervention needed? Would less government intervention help?

4. *Dependence on Foreign Oil*

A crucial international problem where S&T and R&D might be decisive is the need to reduce U.S. dependence on foreign sources of oil. Can our national energy R&D strategy and policies, together with our overall energy policies, reduce this dependence? By how much? When? Are there program or policy changes which would enable us to do better?

5. *Developing Countries*

The two central current interests are the upcoming United Nations Conference (UNCSTD) and the establishment of the Institute for Scientific and Technological Cooperation. The key issues on UNCSTD are the U.S. position at the Conference and the U.S. response to what happens there. On ISTC the key issues are congressional approval, the adequacy of Executive and congressional budgetary support, and the future working relationships between ISTC and AID.

6. Newly Industrializing Countries

Formerly underdeveloped countries which are successfully industrializing present especially difficult problems of S&T and R&D policy. How should U.S. policy and strategy be balanced between cooperation and competition? Should S&T policy on R&D cooperation and technology transfer be aimed at assistance to further development? Or at avoiding creation of new competition with the United States for world markets?

7. Cooperative Agreements

For political and general policy reasons, the United States has entered into a wide variety of arrangements for international cooperation on R&D and S&T matters—through bilateral, multilateral, and regional agreements and through participation in international organizations. An important current need is for realistic evaluations of experience under these arrangements, both to permit appropriate future decisions in particular cases and to provide guidance on future cooperative arrangements. Some general questions: Have both the United States and the other parties benefited? Equally? To the degree expected? Have the agreements been backed up by the necessary financial and other support? On the U.S. side? By the other parties? Are there adequate mechanisms in the U.S. budgetary system for assuring that U.S. commitments in S&T and R&D international agreements are carried out?

8. International Competition in R&D

In setting U.S. R&D program goals, budgets, and policies, the question needs to be faced of what position in science and technology the United States should aspire to hold in relation to other countries. Should the U.S. goal be leadership in all fields? In selected fields? Which ones? How chosen? What is the validity of international competition as a justification for federal R&D programs? In science? In exploration? In technology? What are the prospects for large-scale joint or collective international projects?

9. Foreign R&D

The patterns of R&D and policies on S&T vary considerably among the industrialized nations. What lessons could the United States learn from the R&D and S&T policies of other countries? On institutional arrangements? On the relationship between the government and the private sector? On the role and support of university research?

10. Statistics on International R&D

We have seen that the statistical data base is very weak both for U.S.

international R&D activities, however defined, and for comparative analysis of U.S. and foreign R&D activities. The many different aspects of international R&D, the difficulties of precise delimitation of each category of interest, the practical problems of data collection, and the ever-present pitfalls in interpreting budgetary statistics—all these and many other difficulties have to be recognized. In these circumstances, what steps should be taken—by OMB, State–OES, NSF, Commerce, or industry—to improve the statistical base for international aspects of U.S. R&D? For comparative international analysis, are there any practical steps to improve the international data base on R&D and S&T that should be proposed?

Appendix A

General R&D Statistics Supplementary Tables

Table A-1. National Funds for R&D by Source[1] (in billions)

	1967 Actual	1972 Actual	1978 Est.	1979 Est.	1980 Est.
Current dollars:					
Federal Government	$14.4	$15.8	$23.6	$25.9	$27.9
Industry	8.1	11.7	22.1	24.7	27.3
Univ. & Colleges	.3	.6	1.0	1.1	1.2
Other Nonprofit	.3	.4	.7	.8	.8
TOTAL	$23.1	$28.4	$47.4	$52.4	$57.3
Constant 1972 dollars:					
Federal Government	$19.8	$15.8	$15.4	$15.9	$15.8
Industry	11.2	11.7	14.4	15.2	15.5
Univ. & Colleges	.4	.6	.7	.7	.7
Other Nonprofit	.4	.4	.5	.5	.5
TOTAL	$31.8	$28.4	$30.9	$32.2	$32.5

Source: NSF, data for National Patterns of R&D Resources, 1953-1980. Conversion to constant 1972 dollars by authors.

[1] Amounts represent current operating costs, based on data by performers of R&D, and do not correspond exactly to the figures for R&D in the federal budget used in the text. Capital expenditures are generally excluded.

Table A-2. National Funds for R&D by Performer[1] (in billions)

	1967 Actual	1972 Actual	1978 Est.	1979 Est.	1980 Est.
Current dollars:					
Federal Government	$ 3.4	$ 4.5	$ 6.4	$ 6.8	$ 7.3
Industry	16.4	19.5	33.5	37.7	41.4
Univ. & Colleges	1.9	2.7	4.6	5.0	5.4
Federal R&D Centers Administered by Universities	.7	.8	1.4	1.4	1.5
Other Nonprofit	.8	1.0	1.5	1.6	1.7
TOTAL	$23.1	$28.4	$47.4	$52.4	$57.3
Constant 1972 dollars:					
Federal Government	$ 4.7	$ 4.5	$ 4.2	$ 4.2	$ 4.1
Industry	22.6	19.5	21.8	23.1	23.5
Univ. & Colleges	2.6	2.7	3.0	3.1	3.1
Federal R&D Centers Administered by Universities	1.0	.8	.9	.9	.9
Other Nonprofit	1.1	1.0	1.0	1.0	1.0
TOTAL	$31.8	$28.4	$30.9	$32.2	$32.5

Source: NSF, data for National Patterns of R&D Resources, 1953-1980. Conversion to constant 1972 dollars by authors.

[1] Amounts represent current operating costs, based on data by performers of R&D, and do not correspond exactly to the figures for R&D in the federal budget used in the text. Capital expenditures are generally excluded.

Table A-3. National Funds for Basic Research by Performer[1] (in millions)

	1967 Actual	1972 Actual	1978 Est.	1979 Est.	1980 Est.
Current dollars:					
Federal Government	$ 418	$ 538	$ 900	$1,000	$1,125
Industry	629	593	985	1,115	1,250
Univ. & Colleges	1,457	2,022	3,225	3,545	3,890
Federal R&D Centers Administered by Universities	250	250	410	435	500
Other Nonprofit	285	345	520	555	605
TOTAL	$3,039	$3,748	$6,040	$6,650	$7,370
Constant 1972 dollars:					
Federal Government	$ 576	$ 538	$ 587	$ 614	$ 638
Industry	866	593	642	685	709
Univ. & Colleges	2,006	2,022	2,103	2,177	2,206
Federal R&D Centers Administered by Universities	344	250	267	267	284
Other Nonprofit	392	345	339	341	343
TOTAL	$4,185	$3,748	$3,938	$4,083	$4,179

Source: NSF, data for National Patterns of R&D Resources, 1953-1980. Conversion to constant 1972 dollars by authors.

[1] Amounts represent current operating costs, based on data by performers of R&D, and do not correspond exactly to the figures for R&D in the federal budget used in the text. Capital expenditures are generally excluded.

Table A-4. R&D Performed by Universities and Colleges, by Source of Funds[1] (in millions)

	1967 Actual	1972 Actual	1978 Est.	1979 Est.	1980 Est.
Current dollars:					
Federal Government	$1,409	$1,839	$3,075	$3,315	$3,650
Industry	48	75	150	160	175
Univ. & Colleges	345	575	1,000	1,110	1,225
Other Nonprofit	119	187	360	380	400
TOTAL	$1,921	$2,676	$4,585	$4,965	$5,450
Constant 1972 dollars:					
Federal Government	$1,940	$1,839	$2,005	$2,035	$2,070
Industry	66	75	98	98	99
Univ. & Colleges	475	575	652	682	695
Other Nonprofit	164	187	235	233	227
TOTAL	$2,645	$2,676	$2,989	$3,049	$3,090

Source: NSF, data for National Patterns of R&D Resources, 1953-1980. Conversion to constant 1972 dollars by authors.

[1] Amounts represent current operating costs, based on data by performers of R&D, and do not correspond exactly to the figures for R&D in the federal budget used in the text. Capital expenditures are generally excluded.

Table A-5. Character of Work Performed by Universities and Colleges[1] (in millions)

	1967 Actual	1972 Actual	1978 Est.	1979 Est.	1980 Est.
Current dollars:					
Basic Research	$1,457	$2,022	$3,225	$3,545	$3,890
Applied Research	374	544	1,140	1,195	1,305
Development	90	110	220	225	255
TOTAL	$1,921	$2,676	$4,585	$4,965	$5,450
Constant 1972 dollars:					
Basic Research	$2,006	$2,022	$2,103	$2,177	$2,206
Applied Research	515	544	743	734	740
Development	124	110	143	138	145
TOTAL	$2,645	$2,676	$2,989	$3,049	$3,090

Source: NSF, data for National Patterns of R&D Resources, 1953-1980. Conversion to constant 1972 dollars by authors.

[1] Amounts represent current operating costs, based on data by performers of R&D, and do not correspond exactly to the figures for R&D in the federal budget used in the text. Capital expenditures are generally excluded.

Appendix B

Agency R&D Budget Tables

Table B-1. Department of Defense Research, Development, Test, and Evaluation (RDT&E) (Budget Authority in millions)

Mission Category	RDT&E Program by Mission Category			
	FY 1978	FY 1979	FY 1980	FY 1981
Science & Technology Programs[1]	$ 2,279.0	$ 2,540.2	$ 2,948.2	$ 3,302.4
Strategic Programs	2,332.8	2,382.8	2,410.7	3,200.7
Tactical Programs	4,638.9	5,310.5	5,250.6	5,099.2
Defensewide Intelligence and Communications	552.8	672.2	910.5	1,225.8
Defensewide Management and Support	1,670.4	1,868.3	2,016.1	2,234.6
TOTAL RDT&E	$11,473.9	$12,774.0	$13,536.1	$15,062.7

Activity	RDT&E Program by Activity			
	FY 1978	FY 1979	FY 1980	FY 1981
Research	$ 416.2	$ 476.6	$ 573.3	$ 643.7
Exploratory Development	1,386.3	1,550.6	1,739.0	1,864.4
Advanced Development	2,223.6	2,898.4	2,951.7	3,793.5
Engineering Development	4,225.7	4,235.8	4,410.7	4,463.9
Management & Support	1,345.7	1,408.5	1,515.2	1,665.5
Operational Systems Development	1,876.4	2,204.1	2,346.2	2,631.7
TOTAL RDT&E	$11,473.9	$12,774.0	$13,536.1	$15,062.7

Table B-1 (continued)

Department	RDT&E Program by Department			
	FY 1978	FY 1979	FY 1980	FY 1981
Army	$ 2,418.3	$ 2,709.5	$ 2,927.0	$ 2,993.2
Navy	4,054.3	4,521.9	4,484.0	4,562.0
Air Force	4,222.0	4,597.6	5,005.1	6,272.7
Defense Agencies	779.3	945.0	1,120.0	1,234.8
TOTAL RDT&E	$11,473.9	$12,774.0	$13,536.1	$15,062.7

Performer	RDT&E Program by Performer			
	FY 1978	FY 1979	FY 1980	FY 1981
Industry	$ 7,959.8	$ 8,913.0	$ 9,471.2	$10,890.8
Government In-House	2,984.9	3,268.2	3,368.2	3,411.5
Federal Contract Research Centers (FCRC)	205.9	239.9	281.5	324.7
Universities	323.3	352.9	415.2	435.7
TOTAL RDT&E	$11,473.9	$12,774.0	$13,536.1	$15,062.7

Source: Program for Research, Development, and Acquisition, statement by the Honorable William J. Perry, DOD, 1979.

[1] Technology Base and Advanced Technology Development.

Table B-2. Support by the Army, Navy, and Air Force for Extramural Basic Research by Discipline, FY 1979 (Budget Authority in millions)

	FY 1979	FY 1980
Army Research Office		
Atmospheric & Terrestrial Sciences	$ 2.2	*
Biological Sciences	1.0	
Electronics	6.1	
Materials Science	3.5	
Mathematics	3.9	
Mechanics & Aeronautics	3.5	
Physics	4.0	*
Chemistry	3.5	
TOTAL, Army	$27.7	$34.5
Office of Naval Research		
Physics	$ 9.8	
Electronics	8.8	*
Mathematics & Information Sciences	9.4	
Mechanics	5.6	
Biological & Medical Sciences	7.2	
Behavioral & Social Sciences	5.0	
Terrestrial Sciences	7.9	
Atmospheric Sciences	1.7	*
Materials Science	6.6	
Chemistry	5.0	*
Energy Conversion	4.8	
Ocean Science	27.1	
TOTAL, Navy	$98.9	$126.0
Air Force Office of Scientific Research		
Physics	$10.1	
Terrestrial Sciences	1.6	
Astronomy & Astrophysics	4.0	
Chemistry	9.2	
Atmospheric Sciences	6.1	
Mathematics & Information Sciences	9.5	
Electronics	10.5	
Materials Science	14.3	
Mechanics	14.8	
Energy Conversion	7.2	
Biological & Medical Sciences	4.5	
Human Resources	4.9	
TOTAL, Air Force	$96.7	$113.6

Source: Department of Defense, Office of the Assistant for Research to the Deputy Under Secretary of Defense for Research and Advanced Technology.

*Large increase planned for FY 1980.

Table B-3. Funding for DOD Research by Discipline, FY 1980 (Budget Authority in millions)

	FY 1980
Physics, Radiation Sciences, Astronomy, Astrophysics	$ 79.4
Mechanical & Energy Conversion	58.7
Materials	53.2
Electronics	51.9
Oceanography	48.9
Biological & Medical Sciences	46.6
Chemistry	41.7
Mathematics & Computer Sciences	37.5
Terrestrial Sciences	19.2
Atmospheric Sciences	17.2
Behavioral & Social Sciences	18.1
Aeronautical Sciences	10.2
Subtotal	$482.6[1]
Defense Advanced Research Projects Agency	$ 89.2
Uniformed Services University Health Sciences	1.6
TOTAL	$573.4

Source: Department of Defense, Office of the Assistant for Research to the Deputy Under Secretary of Defense for Research and Advanced Technology.

[1] Includes the amounts shown in Table B-2.

Table B-4. R&D in the Department of Energy (Budget Authority in millions; includes plant and capital equipment)

	FY 1979 Est.	FY 1980 Budget
DOE Appropriations Containing R&D		
1. Energy Supply R&D	$2,707.2	$2,671.8
2. Fossil Energy R&D	759.7	747.6
3. Energy Conservation	235.2	238.9
4. General Science and Research	431.1	474.1
5. Atomic Energy Defense Activities	1,313.7	1,469.0
6. Uranium Enrichment	69.4	80.0
7. Departmental Administration	14.6	18.5
TOTAL, DOE R&D above	$5,530.9	$5,699.9
1. Energy Supply R&D Appropriation		
Solar Technology	$ (315.4)	$ (383.1)
Technology support & utilization	6.7	---
Solar thermal systems	100.1	121.0
Photovoltaics	103.8	130.0
Wind energy	60.7	67.0
Ocean systems	38.2	35.0
Solar Energy Research Institute	3.0	27.0
Program direction	2.9	3.1
Solar Applications	(125.6)[1]	(126.4)
Systems development	41.0	47.0
Demonstrations	66.0	49.5
Market development	16.6	27.0
Program direction	2.0	2.9
Geothermal	158.0	140.9
Biomass	43.0	57.8
Hydropower Projects	28.4	18.5
Electric Energy Systems	41.4	27.5
Energy Storage Systems	59.3	66.4
Nuclear	(1,140.7)	(966.2)
Convertor reactor systems	121.9	104.2
Thermal reactor technology	[23.9 *	[37.0
Advanced reactors	---	10.0
Gas cooled thermal reactors	42.0	---
Advanced isotope separation	54.2	55.0
Program direction	1.8]	2.2]

Table B-4 (continued)

	FY 1979 Est.	FY 1980 Budget
Advanced nuclear systems	$ 54.6	$ 40.3
Space & terrestrial applications	43.1	36.4
Advanced systems evaluations	10.3	2.6
Program direction	1.2	1.3
Breeder reactor systems	741.7	589.9
Liquid metal fast breeder	566.7	462.0
Water cooled breeder	63.0	60.0
Gas cooled breeder	26.0	26.0
Fuel cycle R&D	75.6	30.0
Program direction	10.4	11.9
Light water reactor facilities	10.0	---
Commercial waste management	190.7	199.4
Spent fuel storage	11.4	20.5
Program direction	10.4	11.9
Magnetic Fusion	356.0	364.1
Environmental R&D	219.3	245.1
Basic Research	(220.1)	(275.8)
Basic energy sciences	208.4	252.8
Nuclear sciences	29.7	32.0
Materials sciences	94.1	99.4
Chemical sciences	54.7	69.3
Engineering, mathematical, and geosciences	16.5	25.4
Advanced energy projects	7.5	16.8
Biological energy conversion & conservation	4.0	7.2
Other	1.9	2.7
Technical assessment projects	7.1	11.4
University research support	2.9	9.2
Technical program and policy analysis	1.7	2.4
TOTAL, R&D in Energy Supply Research and Development Appropriation	$2,707.2	$2,671.8
2. Fossil Energy R&D Appropriations (all R&D)		
Coal	$680.7	$662.6
Petroleum	108.1	57.4

Table B-4 (continued)

	FY 1979 Est.	FY 1980 Budget
Gas	$ 33.9	$ 27.6
Fossil Energy General Reduction	-63.0	---
TOTAL, Fossil Energy R&D Appropriation	$759.7[2]	$747.6
3. Energy Conservation Appropriation		
Buildings & Community Systems	$ 86.0[3]	$ 86.0
Industrial Energy Conservation	40.0	42.3
Transportation Energy Conservation	99.2	98.9
Appropriate Technology	8.0	8.5
Inventors Program	2.0	3.2
TOTAL, R&D in Energy Conservation Appropriation	$235.2	$238.9
4. General Science and Research Appropriation (all R&D)		
Basic Sciences		
Life sciences research and biomedical applications	$ 40.8	$ 42.2
High energy physics	297.4	327.1
Nuclear physics	92.9	104.8
TOTAL, General Science and Research Appropriation	$431.1	$474.1
5. Atomic Energy Defense Activities Appropriation		
Inertial Confinement Fusion	$ 144.1	$ 145.9
Naval Reactors Development	296.8	278.4
Weapons R&D and Testing	701.6	763.3
Verification and Control Technology	29.8	37.9
Waste Management R&D and Technology	95.3	196.9
Security and Safeguards	46.1	46.6
TOTAL, R&D in Atomic Energy Defense Activities Appropriation	$1,313.7	$1,469.0

Table B-4 (continued)

	FY 1979 Est.	FY 1980 Budget
6. Uranium Enrichment Appropriation		
Uranium Resource Assessment	$69.4	$80.0
TOTAL, R&D in Uranium Enrichment Appropriation	$69.4	$80.0
7. Departmental Administration Appropriation		
Policy Analysis and Systems Studies	$14.6[4]	$18.5
TOTAL, R&D in Departmental Administration Appropriation	$14.6	$18.5
TOTAL, DOE R&D above	$5,530.9	$5,699.9

Source: Agency budget justification.
*Bracketed numbers total to the entry immediately above.
[1]Includes pending supplemental of $13.75 million.
[2]Includes $50 million recommended for rescission.
[3]Includes pending supplemental of $7.8 million.
[4]Includes pending supplemental of $2.0 million.

Table B-5. The DOE Basic Energy Sciences Budget by Technology[1]
(Budget Authority in millions)

	FY 1978	FY 1979	FY 1980
Conservation	$ 12.6	$ 15.7	$ 21.0
Fossil	14.4	17.2	21.5
Solar	13.1	16.2	22.4
Geothermal	2.8	3.7	5.3
Fission	12.2	12.8	13.5
Nuclear Waste Management	3.3	4.5	10.1
Fusion	11.5	11.6	13.1
Environment & Safety	3.5	4.8	5.9
Multitechnology	31.3	37.9	48.5
Long-Term Advancement of Science	50.4	50.5	56.9
TOTAL	$155.1	$174.9	$218.2

Source: DOE, Office of Energy Research.
[1]Includes operating expenses only; excludes plant and capital equipment.

Table B-6. National Aeronautics and Space Administration Budget Summary (in thousands)

	Budget Plan		
	FY 1978	FY 1979	FY 1980
Research and Development			
Space Transportation Systems:	$1,751,500	$2,009,500	$1,904,000
Space shuttle	(1,349,200)	(1,628,300)[1]	(1,366,000)
Space flight operations	(267,800)	(309,700)	(467,300)
Expendable launch vehicles	(134,500)	(71,500)	(70,700)
Space Science Programs:	$ 404,700	$ 505,400	$ 601,600
Physics and astronomy	(224,200)	(282,900)	(337,500)
Planetary exploration	(147,200)	(182,400)	(220,200)
Life sciences	(33,300)	(40,100)	(43,900)
Space and Terrestrial Applications:	$ 243,900	$ 283,900	$ 344,400
Space applications	(234,800)	(274,800)	(332,300)
Technology utlization	(9,100)	(9,100)	(12,100)
Aeronautics and Space Technology Programs:	$ 333,200	$ 376,400	$ 419,700
Aeronautical research and technology	(228,000)	(264,100)	(300,300)
Space research and technology	(97,700)	(107,300)	(116,400)
Energy technology	(7,500)	(5,000)	(3,000)
Tracking and Data Acquisition	$ 278,300	$ 302,000	$ 332,800
TOTAL, Research & Development	$3,011,600	$3,477,200	$3,602,500
Construction of Facilities	$ 162,340	$ 147,500	$ 157,600
Research and Program Management	889,506	941,469[2]	964,900
TOTAL, Budget Plan	$4,063,446	$4,566,169	$4,725,000
OUTLAYS	$3,983,119	$4,404,100	$4,595,000

Source: Agency budget justification.
[1]Includes proposed supplemental of $185,000,000 for Space Shuttle.
[2]Includes proposed supplemental of $30,969,000 for October 1978 pay increase.

Table B-7. R&D in the National Institutes of Health[1] (Budget Authority in millions)

Institutes	FY 1978	FY 1979		FY 1980
	Actual	President's Budget	Congressional Appropriation	Budget
Cancer	$ 852.3	$ 858.4	$ 916.5	$ 916.5
Heart, Lung, & Blood	425.3	432.2	483.8	480.6
Dental	58.0	57.8	61.4	61.4
Arthritis, Metabolism, & Digestive Diseases	243.0	249.4	287.3	287.0
Neurological, etc.	170.6	173.6	204.4	204.4
Allergy & Infectious Diseases	153.5	159.8	182.7	181.9
General Medical Sciences	182.3	185.0	228.9	233.4
Child Health & Human Dev.	155.4	191.2	189.8[2]	193.7
Eye	80.6	82.4	100.4	99.7
Environ. Health Sciences	59.4	63.9	73.7	72.1
Aging	34.7	35.9	54.3	54.3
Research Resources	144.6	148.5	153.6	153.6
Fogarty Internatl. Ctr.	8.5	8.5	9.0	9.0
Natl. Library of Medicine	37.6	39.8	41.4	41.4
Office of Director	18.9	19.4	20.4	21.1
TOTAL	$2,624.7	$2,705.8	$3,007.6	$3,010.1

Source: Agency budget justification.
[1]Excludes training and "buildings and facilities."
[2]Funds for family planning and population research included at FY 1978 level under continuing resolution. Includes a $10.7 million supplemental request.

Table B-8. Research in the Alcohol, Drug Abuse, and Mental Health Administration[1] (Budget Authority in millions)

	FY 1978	FY 1979		FY 1980
	Actual	President's Budget	Congressional Appropriation	Budget
General Mental Health	$112.0	$135.4	$132.8	$160.2
Drug Abuse	34.1	45.9	42.6	50.3
Alcoholism	16.2	21.2	22.0	25.1
TOTAL	$162.3	$202.5	$197.4	$235.6

Source: Agency budget justification.

[1]Excludes training and community programs.

Table B-9. R&D in the National Science Foundation[1] (Budget Plan in millions)

	FY 1978	FY 1979		FY 1980
	Actual	Budget Request	Current Plan[2]	Budget
Mathematical & Physical Sciences & Engineering:				
Mathematical Sciences	$ 21.4	$ 23.1	$ 22.8	$ 25.5
Computer Research	16.6	18.1	17.4	19.3
Physics	59.9	65.3	63.0	65.0
Chemistry	43.0	47.7	45.6	53.4
Engineering	43.9	49.6	47.6	54.3
Materials Research	59.9	64.5	63.6	70.4
Regional Instrumentation Facilities	3.0	---	4.0	3.8
Industry/University Cooperative Research	.7	---	3.7	4.0
Astronomical, Atmospheric, Earth, & Ocean Sciences:				
Astronomical Sciences	57.6	60.5	59.3	58.6
Atmospheric Sciences	56.4	59.1	58.5	65.9
Earth Sciences	34.1	38.5	36.7	44.3
Ocean Sciences	58.2	63.3	63.0	68.7
Arctic Research	5.3	5.9	6.0	6.0
Biological, Behavioral, and Social Sciences:				
Physiology, Cellular & Molecular Biology	57.6	61.3	62.5	70.3

Table B-9 (continued)

	FY 1978	FY 1979		FY 1980
	Actual	Budget Request	Current Plan[2]	Budget
Behavioral & Neural Sciences	$ 28.5	$ 33.1	$ 34.2	$ 37.1
Environmental Biology	31.5	34.2	34.0	39.2
Social Sciences	24.3	29.4	25.5	26.9
Antarctic Program:				
Research	7.0	6.5	6.5	8.0
Support	41.4	44.2	44.6	47.0
Applied Science & Research Applications	55.1	73.9	62.8	62.4
Scientific, Technological, & International Affairs	23.8	24.3	25.2	25.8
Science Education Development and Research	8.9	11.7	11.7	15.3
Program Development and Management	48.7	54.8	57.9	59.6
Special Foreign Currency Research	4.4	4.9	3.8	4.9
TOTAL	$791.2	$873.9	$859.9	$935.7

Source: Agency budget justification.
[1]Excludes Science Education other than R&D.
[2]Current plan is based on actual legislation and deferrals, carryovers, and adjustments of prior year budgets.

Table B-10. Environmental Protection Agency: "Research and Development" Appropriation[1] (Budget Authority in millions)

	FY 1979 Est.	FY 1980 Budget
By Media		
Air	$ 53.2	$ 72.0
Water Quality	66.6	63.7
Drinking Water	18.0	23.7
Solid Wastes	8.1	8.1
Pesticides	15.2	9.6
Radiation	2.0	2.9
Noise	---	---
Interdisciplinary	20.6	24.5
Toxic Substances	14.8	34.0
Energy	112.0	102.5
Program Management and Support	23.5	27.8
TOTAL	$334.0	$368.7
By Program Area		
Health and Ecological Effects[2]	$ 87.1	$114.6
Industrial Processes	19.3	21.5
Monitoring and Tech. Support	36.3	40.1
Public Sector	46.4	45.4
Energy	112.0	102.5
Anticipatory	9.4	16.9
Program Management and Support	23.5	27.8
TOTAL	$334.0	$368.7

Source: Agency budget justification.
[1] Includes amounts shown in Table B-11.
[2] Includes health effects, ecological effects, transport and fate.

Table B-11. EPA: Office of Research and Development Budget[1] (Budget Authority in millions)

	FY 1979 Est.	FY 1980 Budget
By Media		
Air	$ 53.2	$ 72.0
Water Quality	66.6	63.7
Drinking Water	18.0	23.7
Solid Wastes	8.1	8.1
Pesticides	12.6	9.6
Radiation	2.0	2.9
Noise	---	---
Interdisciplinary	20.6	24.5
Toxic Substances	14.8	34.0
Energy	112.0	102.5
Program Management and Support	4.4	4.6
TOTAL	$312.4	$345.6
By Program Area		
Health and Ecological Effects[2]	$ 84.6	$114.6
Industrial Processes	19.3	21.5
Monitoring and Tech. Support	52.4	62.3
Public Sector	30.4	23.2
Energy	112.0	102.5
Anticipatory	9.4	16.9
Program Management and Support	4.4	4.6
TOTAL	$312.4	$345.6

Source: Environmental Protection Agency.

[1] Includes "Research and Development" appropriation shown in Table B-10 except for small amounts in Pesticides and Program Management and Support.

[2] Includes health effects, ecological effects, transport and fate.

Table B-12. Selected R&D in the Department of Agriculture
(Adjusted Appropriations in millions)

	FY 1978 Actual	FY 1979 Est.	FY 1980 Budget
Agricultural Research:			
Animal Production	$ 62.6	$ 66.0	$ 68.3
Plant Production	122.0	134.1	129.8
Use & Improvement on Soil, Water, & Air	39.3	43.3	45.9
Processing, Storage, Distribution, Food Safety, & Consumer Services	73.3	75.7	67.9
Human Nutrition	15.4	22.0	25.8
Facilities (in Ag. Res. Account)	3.1	8.2	8.2
Contingency Res. Fund	---	1.0	1.0
Adjustments (Carryovers & Reappropriation)	7.5	-2.0	-2.0
TOTAL, Agricultural Research	$323.1	$348.3	$344.9
Cooperative Research:			
Competitive Res. Grants	$ 15.0	$ 15.0	$ 30.0
Ag. Experiment Stations	108.7	109.1	109.1
Research Program	(105.5)	(105.6)	(105.6)
Other	(3.2)	(3.5)	(3.5)
Cooperative Forestry Res.	9.5	9.5	9.5
1890 Colleges & Tuskegee	14.2	16.4	16.4
Special Research Grants	7.2	16.3	11.6
Rural Development Res.	1.5	1.5	---
Animal Health & Disease	---	5.0	---
Administration and Adjustments	2.0	1.7	1.8
TOTAL, Cooperative Research	$158.1	$174.4	$178.3

Source: Agency budget justification.

Appendix C

R&D in Industry Supplementary Tables

Table C-1. Industry Spending for R&D by SIC Groupings: 1976 and 1977 (in millions)

Industry	Total R&D Funds		1977 R&D Funds by Source	
	1976	1977	Federal	Company
Food & kindred products	$ 332	$ 358	*	*
Textiles & apparel	81	81	*	*
Lumber, wood products, and furniture	107	127	$ 0	$ 127
Paper & allied products	313	340	*	*
Chemicals & allied products:	3,016	3,266	294	2,972
Industrial chemicals	(1,323)	(1,460)	(278)	(1,182)
Drugs and medicines	(1,091)	(1,153)	(9)	(1,144)
Other chemicals	(602)	(653)	(7)	(646)
Petroleum refining and extraction	767	913	*	*
Rubber products	501	586	*	*
Stone, clay, and glass products	262	290	*	*
Primary metals:	505	525	25	500
Ferrous metals and products	(255)	(258)	(5)	(253)
Nonferrous metals and products	(250)	(267)	(20)	(247)
Fabricated metal products	355	384	45	339
Machinery:	3,485	3,968	577	3,391
Office, computing, and accounting machines	(2,402)	(2,758)	(546)	(2,212)
Electrical equipment and communication:	5,635	5,943	2,698	3,245

Table C-1 (continued)

Industry	Total R&D Funds		1977 R&D Funds by Source	
	1976	1977	Federal	Company
Radio & TV receiving equipment	$ (52)	$ (58)	$ (0)	$ (58)
Electronic components	(691)	(743)	*	*
Communication equipment and communication	(2,510)	(2,797)	(1,206)	(1,591)
Other electrical equipment	(2,382)	(2,345)	*	*
Motor vehicles & motor vehicles equipment	2,778	3,302	414	2,888
Other transportation equipment	94	117	*	*
Aircraft & missiles	6,322	7,095	5,517	1,578
Professional & scientific instruments:	1,297	1,404	156	1,248
Scientific & mechanical measuring instruments	(324)	(374)	(10)	(364)
Optical, surgical, photographic, & other instruments	(973)	(1,030)	(146)	(884)
Other manufacturing industries	217	245	5	240
Nonmanufacturing industries	8[illegible]	951	443	508
TOTAL	$26,906	$29,895	$10,573	$19,322

Source: NSF, data for Research and Development in Industry 1977.
*Not separately available but included in higher level totals.

Table C-2. Applied Research and Development Performed by Industry, by Product Field and Source of Funds: 1977 (in millions)

	Total	Federal	Company
Ordnances, except guided missiles	$ 288	$ 231	$ 57
Guided missiles and spacecraft	3,035	2,731	304
Food & kindred products	350	*	*
Textile mill products	96	*	*
Chemicals, except drugs and medicines	2,024	40	1,984
Drugs and medicines	959	12	947
Petroleum refining and extraction	473	17	456
Rubber and miscellaneous plastics products	378	*	*
Stone, clay, and glass products	191	*	*
Primary metals	327	6	321
Fabricated metal products	1,157	608	549
Machinery	3,572	234	3,338
Office, computing, & accounting machines	(1,856)	(140)	(1,716)
Electrical equipment, except communication	905	233	672
Communication equipment & electronic components	5,038	2,451	2,587
Motor vehicles & other transportation equipment	2,611	196	2,415
Aircraft and parts	3,125	2,150	975
Professional and scientific instruments	1,260	274	986
Other product fields, not elsewhere classified	3,209 *	1,136	2,073
TOTAL	$28,997	$10,331	$18,666

Source: NSF, data for Research and Development in Industry 1977.
*Not separately available but included in total.

Table C-3. Basic Research Performed by Industry, by Field of Science (in millions)

	1975	1976	1977
Physical sciences	$320	$359	$405
Chemistry	(228)	(253)	(285)
Mathematics	14	18	19
Environmental sciences	15	17	19
Atmospheric sciences	(6)	(6)	(5)
Geological sciences	(5)	(7)	(7)
Oceanography	(3)	(4)	(7)
Engineering (including metallurgy)	191	204	233
Life sciences	122	134	156
Biological sciences	(85)	(102)	(128)
Clinical medical sciences	(37)	(32)	(28)
Other	67	85	78
TOTAL	$729	$817	$910

Source: NSF, data for Research and Development in Industry 1977.

Table C-4. Industry Spending for R&D by Business Week Groupings, 1976 and 1977[1] (in millions)

Industry	1977	% Change from 1976
Aerospace	$ 972	+10.1%
Appliances	124	+12.1%
Automotive: cars, trucks	3,144	+17.9%
Automotive: parts, equipment	245	+15.9%
Building materials	167	+15.4%
Chemicals	1,665	+10.1%
Computers	1,995	+16.3%
Conglomerates	666	+17.8%
Containers	121	-7.6%
Drugs	1,257	+9.9%
Electrical	992	+12.2%
Electronics	293	+16.1%
Food, beverages	348	+15.0%
Fuels	853	+12.1%
Instruments	436	+19.6%
Leisure time	539	+7.7%
Machinery: farm, construction	518	+17.1%
Machinery: machine tools, industrial, mining	340	+5.7%
Metals and mining	143	+4.9%
Miscellaneous manufacturing	541	+18.1%
Office equipment	317	+20.0%
Oil service and supply	154	+13.8%
Paper	95	+8.2%
Personal & home care products	378	+14.2%
Semiconductors	324	+22.1%
Services: engineering, data service, leasing	49	+15.9%
Steel	137	+0.1%
Telecommunications	857	+10.3%
Textiles, apparel	29	+1.3%
Tires and rubber	330	+9.2%
Tobacco	19	+0.8%
TOTAL	$18,048	+16.4%

Source: "R&D Spending Patterns for 600 Companies" (Business Week, July 3, 1978; Copyright 1978 by McGraw-Hill, Inc.).

[1]Based on SEC data for the 624 companies that reported R&D as a separate item and have sales in excess of $25 million and R&D expenditures of at least $1 million or 1 percent of sales, whichever is less.

Appendix D

International R&D Tables

Table D-1. Foreign Performers of Federal R&D (Obligations in millions)

	FY 1972	FY 1975	FY 1976	FY 1977
By Country				
Argentina	$ 0.1	$ 0.9	$ 0.6	$ 1.0
Australia	.5	.9	1.2	1.4
Canada	7.0	8.4	7.1	11.4
Colombia	.1	.1	.3	.2
France	.4	.7	.6	.9
India	5.1	1.8	1.3	2.3
Israel	2.1	3.7	3.3	4.8
Italy	1.4	2.1	1.5	1.6
Japan	.4	1.5	.5	.7
Netherlands	.2	2.7	3.5	.8
Nigeria	.6	*	*	*
Norway	.8	.6	1.0	.1
Pakistan	2.8	2.6	4.6	3.5
Poland	9.1	5.2	7.0	12.5
Sweden	.8	1.8	2.3	2.7
Switzerland	.3	.8	.4	1.3
United Arab Republic	4.1	5.2	11.8	15.1
United Kingdom	2.0	1.9	3.8	10.6
West Germany	.4	4.6	.4	.5
Yugoslavia	10.5	.8	.1	.2
Other countries	7.7	10.6	15.4	11.0
Internatl. Organizations	3.2	5.1	6.4	5.6
TOTAL	$59.6	$61.6	$73.1	$88.2
By Agency				
AID	$ 4.8	$ 5.3	$11.9	$ 5.7
Agriculture	8.6	7.0	8.2	6.0
Defense	10.4	11.1	10.1	15.1
Energy	.7	.6	1.1	10.8
EPA	4.1	1.2	3.5	6.0
HEW	25.4	26.8	29.4	36.6
NSF	1.9	3.7	5.5	3.5
Other	2.9	5.9	3.4	4.5
TOTAL	$59.6	$61.6	$73.1	$88.2
By Character				
Basic Research	$10.1	$11.8	$14.8	$17.4
Applied Research	36.4	29.1	33.9	41.2
Development	13.2	20.6	24.4	29.5
TOTAL	$59.6	$61.6	$73.1	$88.2

Source: Federal Funds, Volumes XXIII, XXV, XXVI, and XXVII, NSF.
*Included in total but not separately available.

Table D-2. Industry R&D Performed Outside the United States by Foreign Affiliates of U.S. Companies (in millions)

Industry	1974	1975	1976
Food & kindred products	$ 18	$ 13	$ 18
Drugs & medicines	76	130	151
Other chemicals and allied products	82	85	93
Stone, clay, and glass products	7	7	8
Primary metals	3	9	10
Machinery	227	287	320
Electronic components	4	7	8
Other electrical equipment & communication	224	225	245
Aircraft & missiles	9	5	5
Professional & scientific instruments	39	49	49
Other manufacturing industries	341	346	382
Nonmanufacturing industries	3	4	4
TOTAL	$1,033	$1,167	$1,293

Source: Research and Development in Industry, 1976, NSF 78-314.

Table D-3. Gross Expenditures for R&D of Major Industrialized Countries

	Canada	France	Germany	Japan	United Kingdom	United States
Equivalent U.S. Dollars[1] (millions)						
1967	$ 795	$2,485	$2,443	$1,940	$2,591	$23,156
Percent of U.S.	3.4%	10.7%	10.6%	8.4%	11.2%	100.0%
1972	1,195	3,581	5,079	5,870	3,275	28,413
Percent of U.S.	4.2%	12.6%	17.9%	20.7%	11.5%	100.0%
1975	1,648	6,062	10,005	10,004	4,763	35,200
Percent of U.S.	4.7%	17.2%	28.4%	28.4%	13.5%	100.0%
1976	1,788	6,287	10,200	11,167	*	38,848
Percent of U.S.	4.6%	16.2%	26.3%	28.7%		100.0%
1977	1,887	6,803	11,677	*	*	42,914
Percent of U.S.	4.4%	15.9%	27.2%			100.0%
1978	1,915	*	14,461	*	*	47,430
Percent of U.S.	4.0%		30.5%			100.0%
Real R&D Growth[2] (percent)						
1967-1972	16.9%	18.4%	78.6%	122.8%	1.3%	-2.6%
1972-1975	8.6%	-7.0%	6.9%	10.5%	6.1%	-4.8%
1975-1976	0.9%	4.0%	-0.1%	2.3%	*	4.5%
1976-1977	4.5%	1.6%	1.2%	*	*	4.0%
1977-1978	0.1%	*	5.3%	*	*	2.8%

Source: Authors' estimates based on GERD data in national currencies assembled by NSF for Science Indicators 1978.

[1] National currencies converted to U.S. dollars at current exchange rates.

[2] Increase in R&D in national currencies less increase in national consumer price indices.

*Not available.

List of References

Citations to all publications referred to in this book will be found in one of four categories below. The "General" section contains publications pertaining to R&D in the federal budget; the "Agency Budgets" lists the congressional budget justifications of the individual agencies and special reports on agency R&D budgets and programs; and the remaining two sections, "R&D in Industry" and "International Aspects of R&D," contain the documents related to the final two chapters of the report.

A. General

American Association for the Advancement of Science; *Intersociety Preliminary Analyses of R&D in the FY 1980 Budget* (Washington, D.C.: AAAS, February 1979).

Blanpied, William A., and Lighthizer, Catherine, eds.; *Research and Development in the Federal Budget: Colloquium Proceedings, June 15–16, 1976* (Washington, D.C.: AAAS, 1976).

Carter, Jimmy; "Message to Congress on Science and Technology" (Washington, D.C.: Office of the White House Press Secretary, March 27, 1979).

_____; "State of the Union Message," in *A New Foundation* (Washington, D.C.: Office of the White House Press Secretary, January 25, 1979).

_____; Text of nationally televised speech on a program to combat inflation, delivered October 24, 1978. (For published transcript see *Congressional Quarterly*, October 28, 1978, pp. 3129–3132.)

National Science Foundation; *An Analysis of Federal R&D Funding by Function;* Surveys of Science Resources Series, NSF 78–320 (Washington, D.C.: Government Printing Office, 1978).

_____; *Federal Funds for Research and Development: Fiscal Years 1977, 1978, and 1979, Vol. XXVII, Detailed Statistical Tables, Appendix C;* Surveys of Science Resources Series, NSF 78–312 (Washington, D.C.: NSF, 1978).

_____; *National Patterns of R&D Resources: Funds and Personnel in the United States, 1953–1978–79;* NSF 78–313 (Washington, D.C.: Government Printing Office, October 1978).

_____; *National Patterns of R&D Resources: Funds and Personnel in the United States, 1953–1980* (in press).

Office of Management and Budget; *The Budget of the United States Government: Fiscal Year 1980* (Washington, D.C.: Government Printing Office, 1979; cited as *The Budget* in text).

_____; "Budget Message of the President," in *The Budget of the United States Government: Fiscal Year 1980* (Washington, D.C.: Government Printing Office, 1979).

_____; *The Budget of the United States Government: Fiscal Year 1979* (Washington, D.C.: Government Printing Office, 1978).

_____; *The Budget of the United States Government: Fiscal Year 1980; Appendix* (Washington, D.C.: Government Printing Office, 1979).

_____; *The Budget of the United States Government: Fiscal Year 1979; Appendix* (Washington, D.C.: Government Printing Office, 1978).

_____; *Data for Special Analysis L: Fiscal Year 1980* (Washington, D.C.: OMB, January 1979).

_____; *Data for Special Analysis P: Fiscal Year 1979* (Washington, D.C.: OMB, January 1978).

_____; *Special Analyses: Budget of the United States Government: Fiscal Year 1980* (Washington, D.C.: Government Printing Office, 1979).

_____; *Special Analyses: Budget of the United States Government: Fiscal Year 1979* (Washington, D.C.: Government Printing Office, 1978).

Phillips, Don I., Cleare, Catherine C., and Patterson, Maria, eds.; *Research and Development in the Federal Budget: Colloquium Proceedings, June 15–16, 1977* (Washington, D.C.: AAAS, 1977).

Phillips, Don I., Curlin, Patricia S., and Petrilli, Ralph L., eds.; *R&D in the Federal Budget; R&D, Industry, and the Economy: Colloquium Proceedings, June 20–21, 1978* (Washington, D.C.: AAAS, 1978).

Shapley, Willis H., and Phillips, Don I.; *Congressional Action on Research and Development in the FY 1979 Budget* (Washington, D.C.: AAAS, 1978).

Shapley, Willis H.; *Research and Development in the Federal Budget: FY 1977* (Washington, D.C.: AAAS, 1976; cited as *AAAS–I* in text).

Shapley, Willis H., Phillips, Don I., and Roback, Herbert; *Research and Development in the Federal Budget: FY 1978* (Washington, D.C.: AAAS, 1977; cited as *AAAS–II* in text).

Shapley, Willis H., and Phillips, Don I.; *Research and Development: AAAS Report III* (Washington, D.C.: AAAS, 1978; cited as *AAAS–III* in text).

B. Agency Budgets*

Agency for International Development; "Congressional Presentation" (Washington, D.C.: AID, 1979).

Alcohol, Drug Abuse, and Mental Health Administration; "Justification of Ap-

* Agency congressional budget justifications are generally published in substantial part or in full in the "Hearings" of the legislative (authorization) and appropriations committees having jurisdiction.

propriation Estimates for Committee on Appropriations" (Washington, D.C.: ADAMHA, 1979).

Department of Agriculture; "1980 Budget Explanatory Notes, Vols. 1 and 3" (Washington, D.C.: Department of Agriculture, 1979).

Department of Commerce; "General Statement: Scientific and Technical Research Programs Funded by the Scientific and Technical Research and Services Appropriation" (Washington, D.C.: Department of Commerce, 1979).

Department of Defense; "Program for Research, Development, and Acquisition: FY 1980" (Statement by The Honorable William J. Perry, Undersecretary of Defense, Research, and Engineering, to the Congress of the United States, 96th Congress, First Session, February 1, 1979).

_____; "Department of Defense Contract/Grant Research Program" (Presentation by Dr. George Gamota, Assistant for Research to the Deputy Undersecretary of Defense for Research and Advanced Technology, February 22, 1979).

_____; "Report of the Defense Science Board Summer Study Group on Fundamental Research in Universities" (Washington, D.C.: Office of the Director of Defense Research and Engineering, October 1976).

Department of Energy; "Congressional Budget Request: FY 1980, Vols. 1–6" (Washington, D.C.: DOE, 1979).

_____; "FY 1980 Budget to Congress: Budget Highlights" (Washington, D.C.: DOE, 1979).

Environmental Protection Agency; "Justification of Appropriation Estimates for Committee on Appropriations, Fiscal Year 1980" (Washington, D.C.: EPA, 1979).

National Academy of Sciences; *DHEW's Research Planning Principles* (Washington, D.C.: Institute of Medicine, March 1979).

National Aeronautics and Space Administration; "Budget Estimates: Fiscal Year 1980, Vols. 1–3" (Washington, D.C.: NASA, 1979).

National Institutes of Health; "Justification of Appropriation Estimates for Committee on Appropriations" (Washington, D.C.: NIH, 1979).

National Oceanic and Atmospheric Administration; *Annual Report to Congress on the National Climate Program* (Washington, D.C.: National Climate Program Office, March 1979).

National Science Foundation; "FY 1980 Budget Estimate to the Congress" (Washington, D.C.: NSF, 1979).

Office of Science and Technology Policy; *Report of the Office of Science and Technology Policy Working Group on Basic Research in the Department of Energy* (Washington, D.C.: OSTP, June 1978).

_____; *Report of the Working Group on Basic Research in the Department of Defense* (Washington, D.C.: OSTP, June 22, 1978).

C. R&D in Industry

Battelle Memorial Institute; *Probable Levels of R&D Expenditures in 1979: Forecast and Analysis* (Columbus, Ohio: Battelle Columbus Laboratories, December 1978).

Department of Commerce; "Draft Reports of the Subcommittees of the Adviso-

ry Committee on Industrial Innovation," *Domestic Policy Review on Industrial Innovation* (Washington, D.C.: Department of Commerce, December 1978).

Economic Report of the President Together with the Annual Report of the Council of Economic Advisers: Transmitted to the Congress January 1979 (Washington, D.C.: Government Printing Office, 1979).

"Forecast 79: $51.8 Billion for R&D," *Industrial Research/Development*, January 1979.

McGraw-Hill Publications Company; *22nd Annual McGraw-Hill Survey: Business' Plans for Research and Development Expenditures, 1977–80* (New York: McGraw-Hill Economics Department, May 20, 1977).

_____; *23rd Annual McGraw-Hill Survey: Business' Plans for Research and Development Expenditures, 1978–81* (New York: McGraw-Hill Economics Department, May 22, 1978).

"1979 R&D Budgets up 10% at Chemical Firms," *Chemical and Engineering News*, January 15, 1979.

National Science Foundation; "Industrial R&D Rises 11% between 1976 and 1977," *Science Resources Studies Highlights*, NSF 79-302 (Washington, D.C.: NSF, March 9, 1979).

_____; *Research and Development in Industry, 1976: Funds, 1976; Scientists and Engineers, January 1977; Technical Notes and Detailed Statistical Tables;* Surveys of Science Resources Series, NSF 78-314 (Washington, D.C.: NSF, 1978).

_____; *Research and Development in Industry, 1977* (in press).

_____; *Science and Technology: Annual Report to the Congress* (Washington, D.C.: NSF, August 1978).

_____; *Support of Basic Research by Industry*, prepared by Industrial Research Institute/Research Corporation (Washington, D.C.: NSF, 1978).

"R&D Spending Patterns for 600 Companies," *Business Week*, July 3, 1978.

D. International Aspects of R&D

Agency for International Development; *Analysis of AID Programs for the U.N. Conference on Science and Technology for Development*, prepared by the International Science and Technology Institute, Inc. (Washington, D.C.: AID, January 26, 1979).

Department of State; *Report to Congress on Science, Technology, and United States Foreign Policy;* submitted pursuant to Section 504(e) of Public Law 95-426 (Washington, D.C.: Department of State, January 1979).

_____; *U.S. National Paper for the U.N. Conference on Science and Technology for Development*, Department of State Publication 8966 (Washington, D.C., January 1979).

Institute for Scientific and Technological Cooperation Planning Office; *Summary Report* (Washington, D.C.: ISTC Planning Office, New Executive Office Building, March 1, 1979).

National Academy of Sciences; *U.S. Science and Technology for Development: A Contribution to the 1979 U.N. Conference* (Washington, D.C.: Government Printing Office, 1978).

National Science Foundation; *Science Indicators 1978* (in press).

"Title V—Science, Technology, and American Diplomacy," in *Foreign Relations Authorization Act, Fiscal Year 1979*, Public Law 95–426 (Washington, D.C.: Government Printing Office, 1978).

About the Authors

Willis H. Shapley was educated at Harvard College and the University of Chicago, where he was a graduate fellow and research assistant in political science. He entered government service in 1942 with the Bureau of the Budget, Executive Office of the President, where for 23 years he specialized in research and development, national defense, and space programs, becoming in the 1960s, Deputy Chief of the Military Division and Special Assistant to the Director for Space Program Coordination.

In 1965, Mr. Shapley became Associate Deputy Administrator at NASA, in which position he served for 10 years as the principal senior assistant to the Administrator and Deputy Administrator of NASA. Since retiring from NASA in September 1975, Mr. Shapley has served as a consultant to the Administrator of NASA, the Office of Management and Budget, the Office of Science and Technology Policy, and other organizations. He is a member of the Space Applications Board of the National Research Council. As a consultant to the American Association for the Advancement of Science, he has been the principal author of the annual AAAS reports on R&D, from *Research and Development in the Federal Budget: FY 1977* to the present volume. Mr. Shapley has received the Rockefeller Public Service Award, NASA's Distinguished Service Medal, and the Career Service Award of the National Civil Service League.

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